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P22-188

325.

MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

THE GEOLOGY OF THE COUNTRY AROUND EXETER.

(EXPLANATION OF SHEET 325.)

BY

W. A. E. USSHER, F.G.S.

With Notes on the Petrology of the Igneous Rocks.

By J. J. H. TEALL, M.A., F.R.S.

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PREFACE.

THE original Geological Survey of the country around Exeter was made by Sir Henry De la Beche, and the ground was described in his famous Report on the Geology of Cornwall, Devon, and West Somerset, published in 1839.

A re-survey of the Secondary rocks was made by Mr. Ussher during the years 1873–76, and the Palæozoic areas were revised by him in 1887.

Meanwhile the Ordnance Survey had commenced the issue of six-inch maps, and eventually published the new series one-inch map of the Exeter district.

It was then decided by my predecessor, in order that the re-survey of the Secondary rocks might not be lost, to transfer the work from the old one-inch map to the new series sheet. It was clearly recognised that the result could not be wholly satisfactory, as time could only be spared for the re-examination of the more important places where the transference showed discrepancies in the topography of the two series of maps. Moreover, to transfer work done on a map without contour-lines to one with these features must always be attended with risk of inaccuracy. Apart from these sources of error, there can be no question of the great advantage of the new map, with its sub-divisions of the New Red rocks and its mapping of the gravels, over the old maps, in which no line had been drawn between the Keuper Marls and the varied divisions of the New Red rocks beneath.

The drifts are not sufficiently extensive to require the publication of two editions of the new map, and one only is issued.

J. J. H. TEALL,
Director.

Geological Survey Office,
28, *Jermyn Street, London,*
27th September, 1901.

4074. Wt. 14808. 500—1/02. Wy. & S.

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THE GEOLOGY OF

THE COUNTRY AROUND

EXETER.

CHAPTER I.

INTRODUCTION.

Sheet 325 of the Geological Survey map embraces an area of 216 square miles in Devonshire, of which about 22 square miles in the south-western corner of the area are drained by the River Teign and its tributaries, and about ten square miles on its eastern border by the head streams of the River Otter. The remaining area is watered by the River Exe and its tributaries the Clist, Culm, and Creedy; of these the Clist alone has a catchment basin confined to the limits of the map.

In a district so well watered there are, as might be expected, many towns and villages, of which, beside the capital city of Exeter, Crediton, Topsham, Broad Clist, Bradninch, and Whimple may be mentioned.

The physical features of the area are much diversified, their characters being dependent on the distribution of the Palæozoic and Secondary rocks, the former consisting of Culm Measure shales and grits, the latter of various divisions of the New Red Sandstone formation.

A small part of the Dartmoor Granite occupies the south-western corner of the area and forms the highest ground, over 1,000 feet; the Culm Measure districts attain heights of 700 feet, and the Secondary rocks near their junction with the Culm rocks on the north margin of the map, near Cadbury and Bradninch, heights of 800 feet or more. Elsewhere the Secondary rocks seldom attain elevations of 300 feet, but in the Pebble Bed escarpment of Woodbury Common, and its northerly continuation along the eastern margin of the map they rise to heights of 500 feet, and at Woodbury Castle 586 feet. In the Culm Measure and adjacent Secondary rock districts the declivities are abrupt, in the sandy and clayey Secondary districts the contour is more or less undulating.

The formations represented on Sheet 325 are the following:—

RECENT - - -	Alluvium.	
PLEISTOCENE - -	Valley or River Gravels.	
NEW RED SANDSTONE SERIES.	Upper Sandstone.	Red sandstone and rock-sand.
	Pebble Beds.	
	Lower Marls.	Red marls with even-bedded sandstone, in the lower part.
	Lower Sandstone and Breccia.	Red Sandstone and rock-sand. Breccia with igneous stones and boulders, brecciated sand and clay. Breccia or gravel of Culm débris.
CARBONIFEROUS -	Middle Culm Measures.	Sandstones and micaceous shales, etc.: Morchard Type. Shales, often splintery with beds of hard grit: Exeter Type.
	Lower Culm Measures.	Even shales with beds of chert and limestone (in places); chert beds; dark mudstones and shales.
IGNEOUS - - -	Exeter Traps - -	Basalt and Trachyte, contemporaneous in Lower New Red Sandstone Series.
	Dolerite, intrusive in Culm Measures.	
	Tuff, contemporaneous in Culm Measures.	
	Granite.	

During the re-survey on the old 1-inch map, no attempt was made to sub-divide the Culm Measures, but during a recent visit to the district evidence was obtained of the presence of the Lower Culm Measures in the southern part of the area. No evidence of Upper Culm Measures (Eggesford type) has been observed.

LITERATURE.*

In Polwhele's "History of Devonshire," 1797 (Chapter iv.) there are many references to the rocks of this district. Making allowance for the state of geological knowledge at the time, the general geology of the county may be said to have been roughly blocked out by him thirty-eight years before the issue of De la Beche's classical Report. The volcanic character of the traps of Northernhay, Thorverton, Spencecombe, and Pocombe is insisted on. Thus in pp. 62, 63:—

> "The species of rock which I mentioned as appearing out of the schistus in many places to the north of the city, is a lava of a fine granulated texture, and of a purplish color intermixed with minute white particles. It pulverises red. It also contains a number of white crystallisations, with which it is spotted: they are of a circular form. The part of the rock, that lies deep in the earth, is of so hard and compact a nature, as to produce some scintillations with steel: the white spots being in general calcareous, effervesce with acids. That part of the rock situated near the surface is of a porous and softer texture, and not effervescent: and what has been exposed

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* See also Appendix, p. 114.

to the weather, instead of having white crystalline spots, abounds in numerous small cavities; and so much resembles pumice-stone, as immediately to excite the idea of its being a volcanic production . . . And those small cavities which gave a honey-comb appearance to the lava, were occasioned by the air-bubbles that rose to the surface of the melted fluid mass." The Quartz porphyry boulders in the Crediton valley breccia are thus noticed—"Out of the schistus near Crediton, arises a compact lava of a purple color, with large crystals of felt-spar, and numerous crystals of pellucid quartz and black mica—the cavities containing farinaceous steatite. . . . Beds of lava and tufa are clearly visible on the sides of the highways near Crediton, Sandford, and several other places." He seems to have regarded all the breccias as volcanic tuffs or lavas—p. 77—"having never been in a state of fusion, but consisting of a mixture of ashes, stones, and other heterogeneous substances, adhering by its ferruginous particles, and forming, altogether, a mass of coarse stone, such as the Heavitree stone." The distribution of the Culm Shillet, Alluvial deposits and New Red of Exeter are given in p. 4 and p. 40. The New Red Marls with gravelly soils are thus referred to—"The country about Rockbear is flat; the soil a stiff clay, mixed with pebbles, that runs through several extensive parishes." Referring to the New Red Pebble beds on p. 76—"The highest part of Woodbury Common, about eight miles south-east from Exeter, is evidently water-formed. Of this there can be no stronger proof than the immense quantities of rounded pebbles, and other waterworn stones, formerly composing a sea-beach, but now the summit of that high common." In p. 61 he connects the pebble beds with those of Westdown Hill, Budleigh Salterton, and gives a description of the various kinds of pebbles.

The decriptions of Vancouver in 1808, as will be seen further on, amplify in many respects the observations of Polwhele. Dr. Shapter, writing "On the Climate of South Devon" in 1842, gives an admirable geological map of the Exeter district.* The work also contains a chapter on the geology and hydrology, pp. 160–207. A very good account by the same author, entitled "A Sketch of the Geology of Exeter and its Neighbourhood," was published by William Roberts, 147, High Street, Exeter, in 1838. Reference is here made to these works as being less likely to attract the attention of the geological reader than the well-known Report of De la Beche. References to papers by Conybeare, Godwin-Austen, and other Geologists, will be found in the Appendix.

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* A second edition of this work was brought out in 1862.

CHAPTER II.

CARBONIFEROUS.

CULM MEASURES.

Sedgwick and Murchison* were the first to assign a Carboniferous age to the Culm rocks of Devon, which as shillet, shellat or schistus had been included in the transition rocks of earlier writers. They divided them into Upper and Lower Culm Measures, regarding the former as the equivalent of the Coal Measures, but the equivalence of the latter as doubtful. The Rev. D. Williams in 1837† divided the Culm into two groups—culmiferous and floriferous shales and sandstones, upon Wavellite schistus and black limestones. These subdivisions were given by Weaver in 1838. The rare mineral Wavellite was found in the basement Culm of Coddon Hill, and the black limestones referred to are also a distinctive but not altogether persistent member of the Basement Culm Measures.

In 1841 Professor John Phillips‡ furnished a classification of the Culm of North and South Devon, in which he places the Coddon Hill chert series at the base of an Upper Shale group containing carbonaceous grits and shales. In other words he links the grits and shales of the Exeter type with the chert horizons of the Basement Culm Measures as one group in South Devon, the corresponding group in North Devon being the Coddon Hill beds alone. Both in North and South Devon, Phillips places the Posidonia limestones and shales next below the Coddon Hill beds, and below them a black shale group in North Devon, and a Lower Shale group (black argillaceous plate), which are the basement beds of this classification. It will thus be seen that Phillips split up the wavellite schistus and limestones of Williams and Weaver into three definite successive groups. The rest of the Culm, including the anthracitiferous seams of North Devon he embraced under the term Upper or Grit group. Phillips' Culm classification is open to amplification, but in view of the disturbed condition of the basement beds in South Devon one hesitates to question the relative order given by him of the three South Devon members of the Basement Beds, although in this map, and in North Devon where the succession has been proved by detailed mapping the Posidonomya beds with occasional limestones occur above the more cherty Coddon Hill Beds. Certainly the latest obtainable evidence is not unfavourable to a passage of the Exeter grit and shale series downward into the

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* Rep Brit. Assoc., vol. v., p. 95, 1836; and Trans. Geol. Soc., ser. 2, vol. v., p. 633.

† Proc. Geol. Soc., vol. iii., p. 115.

‡ Pal Fossils, Devon, Cornwall etc., 1841, p. 194.

Basement Beds. Detailed work between Barnstaple and Okehampton enabled the author* to split up the Grit group of Phillips into an Upper Series of hard even thick bedded grits and shales, and a Lower of sandy grits and irregular grits and shales to which he gave type names from the localities where the distinctions were first recognised, viz., Eggesford and Morchard, but in his classification he adopted the grouping of Phillips as regards the rocks of the Exeter type, including them in the Basement Beds. Nevertheless, as it has been found not only practicable but easy to map the Basement Beds separately from the overlying shales and grits in North Devon, and also in this map near Doddiscombsleigh, and as their marine fauna everywhere points to their separation as a distinct group, it has been considered advisable to alter the classification; to bracket the shales and grits of the Exeter type with those of the Morchard type as Middle Culm Measures, and to regard Phillips' three lower groups (without the rocks of Exeter type) as one group with the Posidonomya beds uppermost. De la Beche† speaks of a line round Dartmoor by Okehampton, &c., which if prolonged by Holcombe Burnell to Exeter separates an area toward Chudleigh where southerly dips prevail in the Culm rocks from prevailing northerly dips. This which then seemed to justify an anticlinal structure would now be taken as the reverse. Except as bearing on the direction of strikes, the dips are misleading in the Culm area, as no angle of dip will be found to persist for many yards owing to the endless small folds, both normal and inverted, which repeat the strata almost indefinitely and are frequently accompanied by small faults and contortion thrusts. The general strike is east and west.

The New Red rocks of the Crediton Valley separate Culm measures of the MORCHARD TYPE from the Culm rocks of the EXETER TYPE.*

The rocks of the MORCHARD TYPE occur on the north of the valley and are the highest Culm Measure rocks included in the district. They consist of more or less thick bedded red, purplish, and greenish-grey grits, and finely micaceous sandstones, together with red slightly arenaceous shaly beds which split into concentric flakes round small ovoidal centres, and grey or greenish argillaceous slates. In this series many beds of grit may occur with little or no shaly intercalation in a regularly or irregularly jointed series, or masses of hard irregularly jointed grit may occur in slates or shales. It is not possible to draw a hard and fast line between the rocks of this type and those of the Exeter type which are locally plicated in with them on the north of the Crediton Valley.

The rocks of the EXETER TYPE of Culm Measures south of the Crediton Valley, consist of weathered dark bluish-grey shales with beds of hard grey or greenish-grey grit often weathering a rusty brown, intercalated singly at irregular intervals in the shales, or in thin beds with shaly partings. As a rule, the grits of this series are evenly bedded. The shales often split in irregular splinters and sometimes contain ovoid concretions coated with ironstone. On their bed-faces they frequently form an irregular mosaic. These characters are well shown in the road section on St. David's Hill, Exeter, and in the cliff section by the Bonhay road leading south from St. David's Station, Exeter.

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* Geol. Mag. for Jan., 1887, pp. 10–17; Proc. Som. Arch. and Nat. Hist. Soc., vol. xxxviii., 1892.

† Report on the Geology of Cornwall, Devon, and West Somerset, p. 116.

* See The British Culm Measures, Proc. Somerset Arch. and Nat. Hist. Soc, vol. xxxviii., pp. 115 and 137, 1892.

The New Red valley of Crediton has therefore been eroded along the plicated margins of these two types of Culm rocks, the lower series prevailing southward; but, as before mentioned, it is impossible to draw any definite boundary between them

The Lower or Basement Culm Measures consist (in descending order) of (1) hard jointed shaly beds, sometimes cherty and intercalated with softer shales and with occasional beds of pale grey limestone, apparently overlying (2) hard even beds mostly of dark chert, and (3) dark grey or blue black hard mudstones, with very thin white bands, and dark shales. This succession must not be taken as invariable, as dark mudstone shales and shaly beds may occur throughout the series and become developed at the expense of its more characteristic members; but, so far as investigations have been made, the fossiliferous horizons in which *Posidonomya Becheri* occurs are to be found in the higher beds in which limestones are occasionally present, or they are represented by brown bands resulting from their decomposition. The uppermost beds of the Lower Culm seem to pass almost insensibly into the overlying shales of the Exeter type.

As will be seen from the detailed notes, there are indications of anticlines bringing up the Lower Culm at and near the surface in the Balls Oak valley, near Tedborn St. Mary, west of Exeter, where small Goniatites were found in dark shales; and in Perridge Tunnel excavated in blackish mudstones which contain Goniatites, south-west of Exeter. These occurrences demonstrate the fallacy of gauging the thickness of the Culm shales and grits of the Exeter type from the comparatively large area they occupy, owing to repetition by plication. The Basement Culm rocks occupy the high ground on the south margin of the area south of Woodlah and west of Doddiscombsleigh on the east of the River Teign, and on the west of it they extend from Southwood through Bridford, round the granite margin by Woodlands and Bridford Wood. These tracts are separated by a syncline of shales and grits of the Exeter type trending southward along the Teign valley. The junction in Scanniclift Wood on the east side of the Teign Alluvium may be a fault.

In the area bordering the granite, banded porcellanised rocks occur of a type met with at Cox Tor, near Tavistock, Peak Hill, near Walkhampton, at Ivybridge, Wrangaton, Brent, and other districts on the margin of the Dartmoor Granite. These are suggestive of altered portions of the harder beds of the Basement Culm, the different types being accounted for by the presence of limestone bands and of volcanic rocks in association with very hard, even shaly, beds and chert bands. Vesicular igneous rock occurs in the Basement Culm Measures on the eastern edge of Scanniclift Copse, and Tuffs occur in them on the south of Doddiscombsleigh.

The area covered by the Basement Culm rocks in Sheet 325 is too small to afford any reliable data as to their thickness, but from the numerous undulations and plications visible in exposures or inferred from directions of strike and angles of dip, it is probable that they are considerably less than 1,000 feet thick, perhaps not above 500 feet.

The following are detailed notes of observations made in the Culm Measure area:—

MIDDLE CULM MEASURES.

1. *North of the Crediton Valley.*

(MORCHARD TYPE.)

A small quarry by the valley between Newbuildings and West Sandford shows 12 feet of hard brown, purplish, and grey micaceous grit, one layer being 5 feet thick, the upper beds are shaly.

Greenish grey clay slates or shales are exposed at West Henstill and near Yarmley, and at the farm east of Yarmley they exhibit "terminal curvature" through the intrusion of roots. Shaly grits resting on thick beds of grey unevenly jointed grit are also shown.

By the high road near Bawdenhayes a quarry exposed thick-bedded, unevenly-jointed, purplish brown micaceous grits under thinner beds of grit, and separated by shaly beds, which exhibit the ovoidal structure before mentioned.

On the east of Sturridge a quarry has been excavated in purplish brown, much jointed grits with occasional shaly partings. One of the lower beds exceeds 5 feet in thickness. By the lane east of Upton Hellions, greenish grey and purplish brown micaceous grits, intersected by numerous even joints, are associated with greyish clay slates or shales, containing hard ovoid concretions.

Between Trew and Lower Westwood hard purplish and greyish-brown sandstones are exposed in a small quarry. Bedding planes are rendered indistinguishable by numerous irregular joints.

About Stockleigh Pomeroy, purplish and brown fine sandstones and shales are frequently visible. South of Cadbury, between the streamlets near Kidlake (West Bowley on the old series map) amongst numerous fragments of brown grit scattered over the surface one containing several casts resembling *Strophomena* was picked up. The stones although unworn may be mixed with *débris* resulting from the denudation of lower New Red rocks. By the streamlet north of Kidlake greenish grey clay slates or shales crop out.

At a bend in the high road above Ash, north of Silverton, a small quarry exposed purplish grits, much split up by joints, but affording good building-stone. N.W. of Bradninch red shales were exposed near Tedbridge.

Near the northern margin of the Spray Down inlier (Sprydon Plantation, etc., on new series map), east of Hele station, near the turning to Pottshayes, soft purplish brown micaceous sandstones and shales were exposed. Lower New Red gravels conceal most of the northern part of the Culm outcrop. which attains its greatest superficial development west of Clyst St. Lawrence, where purplish shales and grits are exposed in several places.

2. *South of the Crediton Valley.*

(Exeter Type.)

On St. David's Hill, Exeter, the Culm shales, for the most part splintery, occasionally break in small rhomboidal pieces. Ovoid concretions coated with ironstone in the Culm shales of Exeter and vicinity may explain any appearances of occasional pebbles noticed in ploughed land to the west of the city.

Culm shales come to the surface at the western end of Union Road, Exeter, and in Northernhay by the path adjacent to Queen's Street Station. In 1878, reddish shales were exposed under a thin gravel deposit opposite the Rougemont Hotel. In the railway cutting, near Queen Street Station, at about 2 chains from Barrack Lane, the Northernhay trap terminates abruptly against Culm shales, the junction being apparently a fault.

Shales and grits dipping generally northward at various angles, are exposed in the lanes near Pinhoe Church, Compasshill Cottage, etc. About Stoke Hill and Rixlade purplish grits occur in blue grey shales and decompose into a red soil.

Near St. Thomas' Union, by the high road north-east of Barley House, the Culm grits and shales give north and south dips indicative of fault or sharp synclinal structure. South of Newton St. Cyres, in Coombland Wood, a quarry displays dark bluish grey shales with intercalated even beds of greenish grey grit dipping at 10° westward. Near the above a quarry in the valley south of Northridge, shows similar shales with beds of dark grey micaceous grit dipping W. 20 N. at an angle of about 8°. The above directions of dip are exceptional. The Culm soils; are stained red near the New Red junction at Upton Pyne, and on the opposite side of the Creedy Valley, but, as a rule, the Exeter type of Culm makes grey brown or pale buff loamy and clayey soils; but where reddish brown or purple grits occur, either in these beds or through synclines of the Morchard type, the soils are red or reddish brown. In a small quarry at bend in lane near West Rowhorne, S. of Newton St. Cyres, light grey shales with beds of bluish grey grit dip northward at about 80°.

East and south of Whitestone the Culm shales and grits dip in a north-westerly direction. At Pitt Farm, south of Whitestone, a small quarry shows bluish grits and shales, weathering grey and brown, and containing brown ironstones nodules enclosing greenish-grey material. The beds dip northward at an angle of 46° and are overlain by two or three feet of soil and comminuted Culm débris. The lanes at Hackworthy, near Tedborn St. Mary, expose splintery Culm shales, which are often met with in this and the Dunsford and Holcombe Burnell districts.

South of Yeoford bluish shales with hard grey grit beds are exposed near the hill tops, their contorted character is shown by the dips in the valley near Winstout, and in the lane on the east of Winstout the shales exhibit terminal curvature. In Great Fulford Park, south of Melhuish Barton, a nearly vertical mass of grit, much broken by joints, strikes W. 20 S. and E. 20 N., further east it has been quarried, and dips N. 20 W., at from 60° to 75°. Whether this is an exceptional mass of grit in this series or a syncline of the overlying series of the Morchard type it is impossible to say.

The entire discordance between the New Red and Culm rocks is very well shown at their junction near Pocombe Bridge by the high road to Exeter.

Near Perridge, south of Holcombe Burnell, shales, often splintery, are associated with thin beds of grit. A road section a little to the north of the turning to Perridge shows several contortions in the Culm. A syncline and inverted anticline occupy a distance of little more than 20 yards.

At Leigh Cross and north-east of it contortions are well shown in the road cutting in shales which are generally splintery and associated with thin beds of grit. Contortions are also exhibited at Lowley.

A small quarry north of Leigh Cross, near the road to Farrants (Great Oak on the old series map), exhibits two thick grit beds (about 4 feet) in the shales, bent in anticlinal and synclinal folds..

North of Dunsford the Culm soils are often reddish on the sides of the valleys and buff on the summits.

Shales with beds of grit are exposed in the road to Teignhouse siding, at, and on the north side of, Woodah, and on the north border of Scanniclift Copse, at the 300 feet contour. In all these cases the exposures are in the vicinity of the Basement Culm rocks, and in the last-mentioned an easterly dip suggests a faulted junction.

By the road on the west side of the Teign alluvium, south of Christow Bridge, shales with beds of grit or sandstone, contain obscure plant traces. Rather wet or marshy ground marks the junction of the Basement Culm rocks with the beds of the Exeter type in places between Scanniclift Copse and Doddiscombsleigh.

LOWER OR BASEMENT CULM MEASURES.

Between Tedborn St. Mary, Whitestone, and Holcombe Burnell there appears to be an anticline of the uppermost beds of this series in the valley between Five Mile Hill Cross and Ball Oaks. In an exposure of decomposed blackish ferruginous rock, intersected by filaments of quartz and associated with shales, small, badly preserved *Goniatites* were obtained, suggesting the presence of *Glyphioceras sphæricum.** On a latitude about two miles south of the above, there is evidence of the uppermost beds of this series in Perridge tunnel, described further on in notes on the Teign Valley Extension Railway. The boundary of the Basement Culm rocks on the east of the Teign Valley is fairly well marked by feature except on the western slope.

An old quarry in an orchard E.S.E. of, and 10 chains from, Woodah farmhouse, exhibits partial exposures in one of which, 6 feet in height, an anticline, apparently running W. 30° S. and E. 30° N. is visible in a bed of grey limestone about 1 foot thick, under shales containing *Posidonomya Becheri*, with hard decomposed brown bands, and hard even mudstones and shales.† (See Fig. 1, p. 10).

At 10 chains south of Woodah a quarry on the 6-inch map (91° N.E.) shows the characteristically even-bedded and jointed Coddon Hill beds, mostly chert contorted as in Fig. 2, p. 11, and no doubt underlying those in the exposure last described. Near the New Inn, Doddiscombsleigh, vertical Coddon Hill beds containing chert are exposed by Down Lane, striking N.W. and S.E. Further W., near Christendown Clump, chert beds are exposed dipping S. by E., and by the road to Ashton at Shute an adit for manganese working has been driven along the bedding in chert beds.

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* Approximate millimeter measurements: Diameter, 13; thickness, 8; height of outer whorl, 7; amount of inclusion, 3½; width of umbilicus, 2.

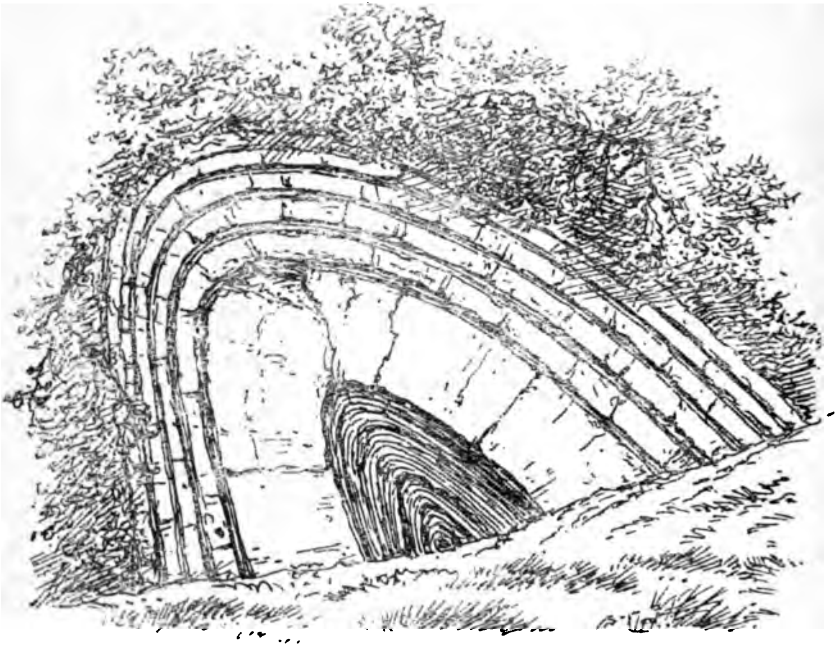
† The Rev. D. Williams (Trans. Roy. Geol. Soc. Corn., vol. vi., pp. 122–138) alludes in a footnote to the discovery of "a beautiful tooth in the Posidonia limestones of the Coddon Hill grit series" at Doddiscombsleigh pronounced by Prof. Owen to be a genus of fish hitherto (1843) only found in the Urals.

On the south of Down Lane, near Addiscombe Lane, the surface stones thickly scattered over the ploughed land denote the presence of cherty rocks of the Peak Hill type before referred to, and of hard mudstones, &c., of the Coddon Hill series. (See pp. 6, 7.) Above Scanniclift Copse on the summit the hard even Coddon Hill types are exhibited in the surface fragments ploughed up.

In Harehill Plantation, south of Doddiscombsleigh Church, an adit for manganese has been driven in hard brown stained dark mudstones, apparently associated with chert. On the summit south and south-east of the plantation the surface stones prove the presence of chert beds and of hard mudstones.

The Basement Culm rocks on the granite margin consist of the various types of indurated shales, mudstones, and cherts. Masses of bluish grey and green banded cherty or porcellanised rocks of the Peak Hill type, before mentioned, and of quartz veinstone are often met with between ridford and Stone Farm, also in Bridford Wood, where they dip off the northern margin of the granite. South of Bridford Wood and west of Lowton a nearly east and west fault cuts off a small patch of the hard banded rock, which is surrounded by granite.

FIG. 1.—*Section in Quarry near Woodah, Doddiscombsleigh.*



As regards the Basement Culm Measures and the igneous rocks interpenetrating or associated with them in Sheet 325, it is right to mention that the area west of the Teign has not been re-examined since it was surveyed in 1887 on the old series map. Moreover, east of the Teign, S.W. from Christendown Clump, the dolerite boundaries have not been checked since their transference to the new series map.

BASIC IGNEOUS ROCKS.

Near the northern end of Scanniclift Plantation and within its western margin a band (or bands) of vesicular igneous rock, occurring apparently on the strike, is exposed in a quarry in or on hard Lower Culm rocks; as there is evidence of Coddon Hill beds above the igneous rock, these are probably representatives of the hard dark mudstones of the lower part of the Basement beds. At 30 chain south of Doddiscombsleigh Church it is possible that the igneous rock may be a contemporaneous lava, as it seems to follow the strike and is more or less vesicular.

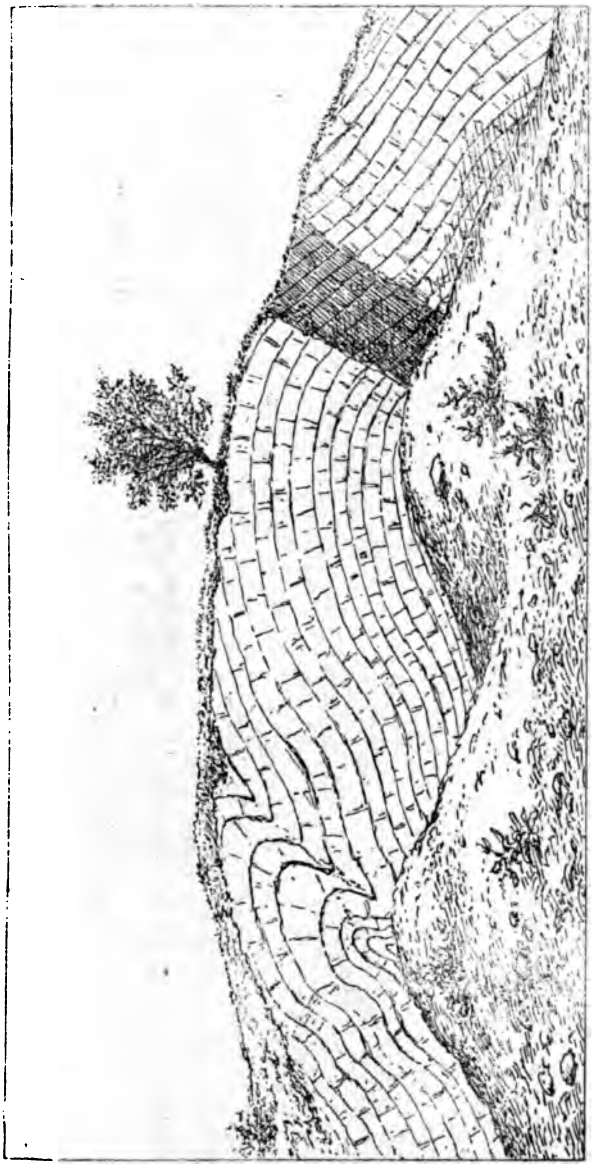
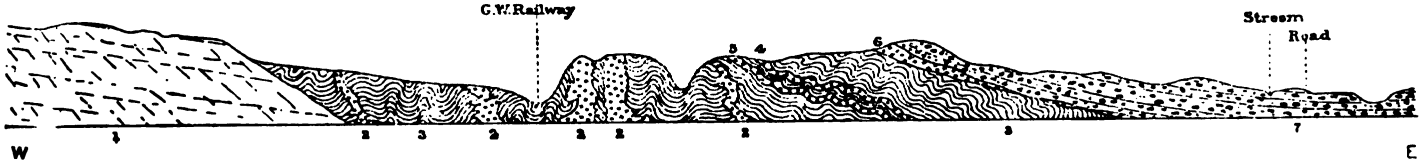


FIG. 2.—*Chert Quarry, south of Woodah, Doddiscombsleigh.*

At Misleigh Copse, and in a quarry on the south of it, whitish

FIG. 3.—*Section along the southern margin of the area, from near Heltor to Bicton Common.*



New Red Sandstone Series -
- 11. Upper Sandstone.
- 10. Pebble Beds.
- 9. Lower Marls.
- 7. Sand-rock overlaid by Breccia, and passing westwards into Breccia (8) with boulders of quartz-porphyry.
- 6 Olivine-trachyte.

3. Culm Measures, with contemporaneous tuff (4) and dolerite (5).

2. Dolerite—intrusive.

1. Granite.

tuffs appear to be associated with the hard Culm mudstones, but it is not possible to trace them for any distance. On the south of Misleigh Copse a trace of dolerite is also visible.

Without careful re-examination it is not possible to prove the existence of volcanic rocks in the area west of the Teign in Sheet 325. There can be no doubt as to the general correlation of the volcanic rocks of the Doddiscombsleigh district with those of the Tavistock area, and as regards the dolerites where their patchy and irregular occurrence justifies a belief in their intrusive origin, it is not improbable that some at least may be parts of necks or pipes of submarine volcanoes active during the deposition of the Lower Culm measures. (See Fig. 3, p. 12.)

An interesting rock occurs on the south margin of Sheet 325, or just within the adjacent map on the south, Sheet 339: it is chiefly evidenced by dull purplish stones with reddish blotches ploughed up in a part of the eastern summit of Doddiscombsleigh Hill. This rock resembles one intrusive in the Lower Culm Measures of Ashbrittle in West Somerset, described by Mr. Teall as "undoubtedly allied to the Exeter traps."

Dolerites* occur on the margin of the map south of Doddiscombsleigh and south of Woodah. The rocks are for the most part much decomposed. Small patches of Dolerite are evidenced by boulders west of Southwood. The hill above Stone farm consists of Dolerite which forms crags on the slope west of the farm. A smaller mass occurs close to it on the west. On the north Dolerite was exposed by the road to Bridford. The contiguous patches on the west (north of the road to Bridford) are marked by feature. There are craggy exposures of the rock in the smaller patch; the rock in the larger patch is much decomposed, a pit in one spot showing coarse brown friable sand, the result of disintegration *in situ*. There are four patches north and north-west of Bridford; the largest of these is indicated by surface boulders and by feature; the small patch near the granite has been inferred from large dolerite boulders on a flat marshy tract with a soil of granite and Culm *débris*; the eastern patch is exposed by the road toward Weeke Barton. Near it on the north is a small knoll of dolerite which may extend for a quarter of a mile westward.

A small patch of dolerite occurs in Cod Wood, W.S.W. of Dunsford.

GRANITE.

Granite is confined to the south-western corner of the area. The rock is generally of a coarsely porphyritic character, and irregularly susceptible to surface disintegration, to which the flat tracts of some extent at and near the sources of some of the streams must be ascribed.

Heltor Rock, or Hell Tor, is a fine bold pseudobedded granite mass, rising abruptly to a height of from 30 to 40 feet on the west and to 25 feet on the east side, owing to the inequalities in the surrounding slope. Its height above sea-level is 1,036 feet Its top is pitted with rock-basins. The upper part is cleft by a nearly vertical open east and west joint; in the section thus exposed an impersistent bedlike band of finer granite 2 feet in thickness occurs in the coarsely porphyritic rock. The longer axes of the large orthoclase crystals exhibit no special orientation, but they are as a rule more or less parallel to the pseudobedding. (See Fig. 4.)

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* The major part of these rocks occur in Sheet 339, the adjacent map to south, where specimens were collected and examined petrologically by Dr. F. H. Hatch.

On the hill east of Heltor Rock the granite exhibits thin shelvy pseudobedding, which, as the vertical joints are ill-developed, gives rise to low cake-like tors. A pit 8 feet deep on the east of Heltor Rock has been excavated in granite sand under from 2 to 4 feet of small irregular granitic rubble; these disintegrated materials may have been slightly moved by sub-

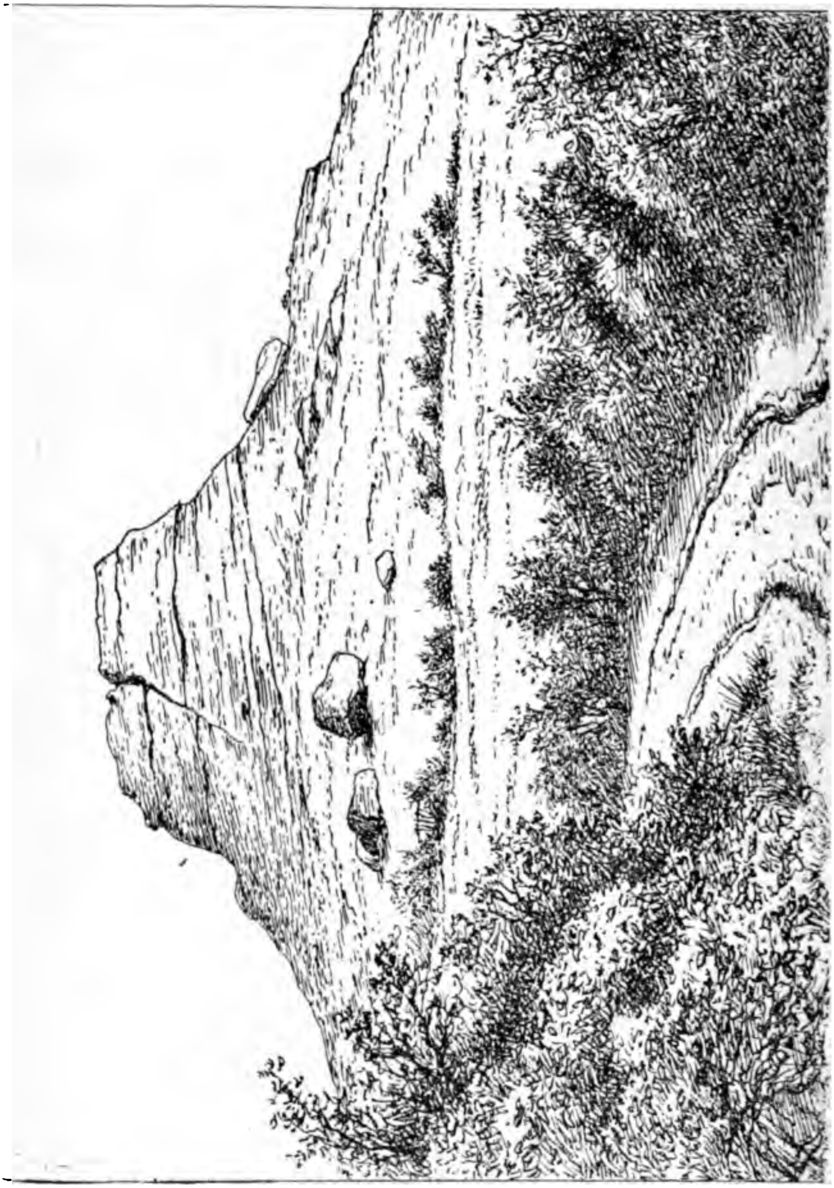

FIG. 4.—*Heltor Rock*

aerial agencies. Polwhele says, "To the south of Exeter the heights of Hennock afford sufficient evidences of a volcanic fire." In recent years the idea of a Dartmoor volcano, of which the granite would be the basal wreck, was advocated by Mr. R. N. Worth.*

TEIGN VALLEY EXTENSION RAILWAY.

The cuttings of this line were examined, March 26th and 28th, 1900. From Leigh Cross to Farrants the line crosses the strike of the Culm rocks nearly at right angles; from Farrants to Cotley Wood it crosses the strike obliquely, coinciding with it in Britton Park. On entering Cotley Wood a northerly bend exhibits the rocks across the strike up to the short tunnel east of Culver and for a few chains beyond it whence its course is either along the strike or more or less nearly coincident with it until the line enters the New Red area through the Trap mass of Westown.

There are about sixteen cuttings affording, with two or three exceptions, excellent sections of the Culm Measure grits and shales of the Exeter type. In the first, second, and third cuttings from Leigh Cross the alternations of thin grit beds with shale seams, and shales with somewhat thicker grit beds display many contortions, small faults and contortion slides or thrusts, while the weathering is rusty or orange brown. The fourth cutting, in a distance of about 20 yards from its commencement shows two masses of decomposed greenstone separated by contorted Culm beds for about 14 yards. The first mass exhibits spheroidal structure, and might possibly be a lava, but the second is a dyke with horizontal joints, and only 4 feet wide.

The seventh cutting shows beautifully even thin grit bands with shale partings forming a sharp anticline in one place, and in another so squeezed and contorted that it is almost impossible to trace the disturbed beds continuously. In the eighth cutting there is a grit bed a foot thick which is an exceptional thickness. The short tunnel near Culver is bricked, but the grits and shales are exposed in cuttings at both ends.

On either side of the Perridge Tunnel the ballast consists of dark grey hard mudstone or clunch somewhat recalling the "clift" of the Somerset coalfield. The rock is banded with arenaceous material in places, circular bunches of pyrites suggest the metamorphosis of small Goniatites on the bed surfaces, and Goniatite fragments were obtained unmineralized. These exhibit the characteristically curved fine striæ of the tests of *Glyphioceras crenistria*. On examining the sides of the tunnel this material was found to be *in situ*, in places vertical, in places slightly inclined. It contains harder beds or masses, seemingly somewhat similar in character to the grits of the Exeter type, which with associated shales form the mouth of the tunnel at either end, and display an anticlinal structure. The surface in the highest part over the tunnel is 240 feet above the rails, so that this anticline of the top beds of the Basement Culm measures does not come to the surface. The cracks or joints in the hard dark mudstone are frequently coated with a black glaze. Neither limestone nor chert was found. Dynamite was used in the tunnel, but blasting with ordinary powder was found very much more efficacious in the broken shales of the Exeter type.

From Perridge Tunnel, eastward, the cuttings run along the strike of the Exeter shales and grits, and the contortions causing them to change in angle and direction of dip, much inconvenience has been occasioned by the irregular splintery jointed shales slipping into the cuttings. The shales often weather a dirty white, and contain fragmentary plant traces as in the cutting at Fordland Cottage. Unfortunately there are no cuttings deeper than the subsoil at the junction of the Culm and Trap, the yellow clay under a wash of brown soil, however, proves the junction as mapped to be quite correct. The cuttings in the Trap were not completed, nor were those in the New Red breccia. The latter contains boulders of quartz porphyry in places, but the majority of the stones seem to have been derived from the Culm grits; the matrix is an earthy or loamy sand, and is in places banded with dark seams.

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* The Dartmoor Volcano, Trans. Plymouth Instit. 1888-89. In Trans. Devon Assoc. for 1888, vol. xx., pp. 146, 150, 151, 152, references to this district occur.

The occurrence of Basement Culm Measures at Perridge Tunnel confirms the observation made in the valley at Ball Oaks, near Tedborn St. Mary, and being in latitude intermediate between the Balls Oak valley and Woodah, demonstrates the nature of the Culm structure, as, in spite of folds, contortions, and faults, practically amounting to an almost horizontal series with imperceptibly gentle major undulations. Mr. Blewitt, engineer of the Teign Valley Extension line, kindly placed at my disposal the sections of the line showing the depth and position of the cuttings, and afforded me all the information in his power as to the nature of the strata encountered.

Reference has been made to evidences of close connection amounting to a passage from the shales and grits of the Exeter type downward into the Basement beds. In Mr. Vicary's collection, Goniatites labelled from three localities in which there are no signs of the occurrence of characteristic Basement beds point to this. The localities are Cocktree Moor, near North Tawton, on the southern border of the New Red Valley of Crediton in Sheet 324; near Pinhoe Church in raddled shales and *grits;* in the cliff by Bonhay Road, Exeter. The writer visited Pinhoe and the Bonhay road section recently, but beyond occasional plant traces his search was unrewarded by the discovery of fossils. Assuming that the Goniatites in the three localities mentioned mark the presence of the lowest beds of the Exeter type, their occurrence points to the local inclusion of shales and grits in the upper part of the Basement beds, and affords a further confirmation of what has been said as to the comparatively shallow structures by which the members of the Culm are kept at the surface over an extent of area wholly incommensurate with their thickness.

The further consideration of the Culm Measures will be treated in the description of their occurrence in Sheet 339, the adjacent map on the south, in which the full classification will be given.

CHAPTER III.

NEW RED SANDSTONE SERIES.

"The term New Red Sandstone was originally applied to the red rocks that occur between the Coal Measures and the Lias, and it was used by Conybeare to distinguish these strata from the Old Red Sandstone."* De la Beche† uses the term as including all the Secondary strata embraced in the map under description. Although it is highly probable that the lower beds, including the Trap rocks, represent German Permian horizons, there is considerable difference of opinion as to where the boundary between Permian and Trias should be taken in Devonshire. Some writers regard the Budleigh Salterton Pebble bed as representative of the Bunter Pebble beds of the Midland counties, and would place everything beneath it in the Permian. Pengelly, in view of the perfect conformity of the whole successsion, to which he ascribed the enormous thickness of nearly five miles, considered that Keuper beds only might be represented.‡

In my opinion, the physical break between the Budleigh Salterton Pebble-bed and the underlying marls might be taken as a boundary between Keuper and Bunter; and indeed this bed of well rolled pebbles might reasonably be considered homotaxeous with the Muschelkalk, representing the incursion of the sea into salt lakes and estuaries during a temporary depression.

As regards the division between Permian and Bunter the matter may be regarded as *sub judice*, although provisionally I prefer taking it above the outcrop of the sandstones which overlie the Heavitree breccia, and at the base of the Lower Marl series.

Apart from the uncertainty as to classification, the resumption of the old term New Red Sandstone is justified on the ground of the great discordance between the Culm Measures, and the lowest beds of this series which rest on the denuded edges of Culm rocks of different horizons, and upon Upper, Middle, and Lower Devonian rocks. In the interval, represented by this discordance, not only were the Palæozoic rocks folded and contorted as we now find them, but so drastic a denudation succeeded the movement that in places the whole mass of the Culm Measures as well as the Upper and Middle Devonian rocks, were removed to permit of the unconformable super-position of the basement New Red beds of the Cockington and Paignton area upon Lower Devonian rocks.

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* H. B. Woodward. Geology of England and Wales, 2nd edit., 1887, p. 207.

† Geological Manual, 1832, p. 390. Report on Geology of Cornwall, etc., 1839. Mem. Geol. Sur., vol. i., p. 239, etc., 1846.

‡ Trans. Plymouth Institute, 1862-63 and 1864-65.

In 1869, Mr. Whitaker* described and figured the New Red succession from Babbacombe Bay to Seaton, the basement beds being generalised as Breccia and Red Sandstone. The general results of the re-survey of the New Red rocks from the Bristol Channel to the English Channel were given by me† in the years 1875 and 1876, and the position of the Watcombe clays was defined in 1877.‡ The first detailed map of the relations of the New Red sub-divisions appeared in 1889,§ illustrating their mode of occurrence in West Somerset.

The coarse marginal accumulations of the New Red derived directly from the Culm Measures on which they rest on the north of Bradninch, Silverton and the Crediton valley, and on the Sprydoncote Culm inlier, are earthy gravels which for a long time were regarded as superficial. These are here alluded to as New Red gravels, that term best denoting their rubbly unconsolidated character.

LOWER SANDSTONE AND BRECCIA.

The earliest visible Secondary strata in the area consist of fragmentary rocks partly consolidated into breccia, partly more or less incoherent earthy sand and gravels, brecciated clay, loam and sand, and red rock-sand and sandstone. Between these classes of material there is no doubt to some extent a general horizontal interchange, such as would be found in the irregular outward extension of the gravels and coarser breccias from the Culm measure margin into finer deposits forming simultaneously in deeper waters. In this way the distribution of coarser and finer materials in the Exminster, Bradninch, Silverton and Thorverton districts may best be explained. As false-bedding is very common both in sands and breccia, stratigraphical relations are not necessarily indicated by dips taken in partial exposures.

There are also local changes in the character of the materials, due to the following causes:—Firstly, variability in the sources of supply, such as would be caused by the local absence or paucity of grit beds in the Culm measures of the Exeter type, giving rise to clayey deposits, whilst the denudation of sandstones and grits plentifully associated in shales (as in the beds of the Morchard type) would afford material for gravelly sand, and loam or sand, according to the conditions of deposit. Secondly, the irregularity of the shore line and of the floor of the area of deposit. To this the somewhat enigmatical distribution of the rocks on and surrounding the large Culm inlier south of Bradninch may be partly due. The disappearance of the breccias on the Culm margin from Whipton and Pinhoe to Upton Pyne is probably occasioned by the conformable overlap of the overlying sands on the promontory.

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* Quart. Journ. Geol. Soc., vol. xxv., p. 152, 1869.

† Geol. Mag. for April, 1875, dec. ii., vol. ii., no. 4, and Quart. Journ. Geol. Soc., vol. xxxii., 1876, p. 367.

‡ Trans. Devon Assoc. for 1877.

§ Proc. Som. Arch. and Nat. Hist. Soc., vol. xxxv., 1889. The divisions have since been shown on the four-mile to one-inch maps of the Geological Survey.

From the foregoing remarks it might be inferred that the general distribution of the sands and breccias has no stratigraphical value whatever; but this is not the case, as the fact of the general easterly tilt of the rocks proves that the sands as a whole must be above the breccias as a whole in the district south of Broad Clyst; but beyond this the irregularities of deposition come into play, and in the narrower channels there is reason to think that comparatively fine sediments were overlain and overlapped by the coarser materials, as east and north of Killerton.

No geologist traversing the breccia districts of Crediton and south of Exeter can fail to be struck by the abundance of igneous rock fragments in them. Acid, as well as basic rocks, must have been denuded to furnish the Murchisonite and other fragments of granite origin,* the stones and large boulders of quartz porphyry and the fragments of Trap. The conspicuous crimson patches on the map denote contemporaneous Trap rocks, which will be described in the sequel. If these eruptive masses were all on the same horizon they would form a valuable plane of division between pre- and post-trappean sediments, but such a supposition is not borne out by the general stratigraphical relations between the breccia and sandstones, and it would necessitate the unconformable overlap of the Marl series on the latter (see pp. 45, 63, 64). Moreover, the Exeter and Dunchideock lavas are very much lower in the series than those of the Killerton and Silverton district, the Posbury and Spencecombe patches being perhaps of intermediate date of eruption.

These trap patches in the Crediton and Exeter districts enter largely into the composition of the overlying breccias, and were without doubt most extensively denuded during their accumulation. In the district south of Exeter, where large boulders of quartz porphyry occur in the breccia, it is very probable that acid rocks may have penetrated the Culm in dykes, sills, and necks, and have participated in the destruction to which the volcanic cones were subjected.

The breccias of the area north of Spencecombe, are for the most part subjacent to the Traps, and in their vicinity display an ashy felspathic character indicative of the commingling of tuff, with the sediments forming just before the efflux of the lavas. The lavas of the Silverton and Killerton area, even allowing for their more central position in the New Red, are much higher in the series, and for the most part above the breccias and sands surrounding them; whilst the Dunchideock and Exeter lavas are at or near the base of the series as far as exposed. It is necessary to bear in mind the fact that the relative thickness of sediment underlying the lavas has less to do with their relative horizons than the thickness of the rocks overlying them; because eruptions near a basin of deposition would probably overlap the area of deposit, and encroach on the older rocks; this is the natural explanation of such relations as are exhibited by the Traps of Exeter, Yeoton, and Posbury, and of the Spencecombe district to the Culm Measures, and to the various thicknesses of New Red sediments underlying them. The presence of false bedding and the irregular relations of the materials render the tracing of faults in the Lower New Red impracticable. The absence of exposures in the valleys of the Bradninch and Silverton districts precludes the desirability of attaching too much significance to the lines on the map, as brecciated beds may cross these valleys on an east and west strike.

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* Pengelly considered that pebbles of schorlaceous porphyritic and elvan granite occurred in the Lower New Red beds of Haldon, and were derived from Dartmoor granite. Trans. Dev. Assoc., vol. i., part 1, pp. 48, etc.

In an early paper by Dr. J. F. Berger and in the Outlines of the Geology of England and Wales by Conybeare and Phillips, published in 1822,* will be found many classic passages referring to the New Red rocks of the Exeter district and to the occurrence of contemporaneous amygdaloidal traps. In the footnotes is given the most complete catalogue extant of the constituent rocks in the Teignmouth and Dawlish breccias, of which the breccias of the Exeter map are the northerly continuation. The fragments of felspar, afterwards named Murchisonite, to which especial attention was subsequently directed by G. W. Ormerod,† are mentioned, and the Heavitree breccia is admirably described. Mr. W. Vicary‡ pointed out the close similarity of analyses of Dartmoor felspar and Murchisonite, the red colour of the latter being ascribed to secondary causes. He instances the much lighter tint of Murchisonite in buff sandstones of Exminster than in the red sandstones in the same neighbourhood.

In the following detailed notes it has been found inexpedient to follow the lithological varieties separately throughout the district, owing to the variability and the local or irregular extension of different types, the more convenient plan of topographical treatment, in districts given below proceeding north from the south margin of the map, has been adopted, it being thereby rendered much easier to trace the places referred to on the map:—

1. *District south of Exeter*, and west of the river Exe.
2. *Exeter district*, extending to Clyst Honiton, and Exton.
3. *Broadclyst district*, east of the river Culm.
4. *Bradninch and Silverton district*, between the rivers Exe and Culm.
5. *Crediton district*, from the river Exe to western margin of the map.

Subject to this treatment the general lithological distinctions will be separately followed as far as possible.

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* Pp. 292–298. See also De la Beche's Report, pp. 204, 208, 217, 218.

† On the Murchisonite Beds of the Estuary of the Exe, Quart. Journ. Geol. Soc., vol. xxxi., p. 346, 1875.

‡ Trans. Dev. Assoc., 1867–8, vol. ii., part 1.

1. *District south of Exeter.*

In this district breccias largely prevail overlying the Trap rocks on the west, and passing into and underlying sands and sandstones on the east. The oldest Secondary rocks of this district are doubtless represented by impersistent strips of sand and gravel underlying the Traps, which will be noted in the chapter on Trap.

Near Kennford by the road to Haldon breccia of closely aggregated small sub-angular fragments of igneous and grit rocks in a sandy matrix is exposed: a type often encountered in the vicinity of Exminster and other parts of the Crediton Valley. By the same road near Haldon, in Sheet 339, the breccia contains numerous granitoid fragments (Murchisonite plentiful), and boulders of quartz porphyry, in a red-brown clayey and loamy matrix, bedding being shown in the assortment of the stones. These exposures are typical of the breccias of Dawlish and the breccias of Teignmouth respectively.

In the wood between Shillingford and Brenton hard breccias, resembling the Heavitree breccia, were quarried, the stones consisting of grit and igneous rocks, angular and sub-angular, for the most part of small size. Mr. Clement Reid noticed the angular character of the fragments in the breccia exposed in a road at half a mile east from Dunchideock Church, also the occurrence of "several large detached blocks of trachyte" near the exposure. Mr. Bernard Hobson* notes that "a mass of genuine quartz porphyry measuring about 4 feet by 1 foot" occurs apparently in the New Red Breccia by the road opposite the entrance gate to Dunchideock House. The following section was disclosed in a lane cutting north-east of Idestone, between Combes Head and Marshalls Farm; the succession is given in descending order:—

Red rubbly gravel of igneous and grit rock fragments.

Red and grey (variegated in bands and spots) loam and loamy clay.

Tough pale grey sand-rock, broken by numerous joints.

Dark red sandy loam, mottled with grey streaks and patches, with impersistent strips of sand and fragments of igneous rock, and of altered rock like the baked sandstone associated with the Traps.

Rubbly grey and red breccia with numerous fragments of the same character as those in the overlying bed.

Tough brecciated red sandstone.

Coarse rubbly breccia with fragments of igneous and altered rocks, giving place to dark red rubbly breccia mottled with grey streaks, with loamy matrix.

Between Marshalls Farm and Bowhay Farm, by the road to Ide, the breccia is well exposed; it contains small angular and sub-angular fragments of grit, shale (occasionally cherty), decomposed trap, Murchisonite felspar (often decomposed to whitish sand) and pieces of altered sandstone, occasionally large and unworn, and in places large boulders of quartz-porphyry, also a single limestone fragment was obtained.

Between Ide and Alphington the breccia contains numerons small, nearly angular fragments of igneous and Culm rocks; near Ide it varies from a brecciated loam to a dense red gravel in loamy matrix with grey streaks. North of Ide the beds overlying the Trap rock consist of red and dark brown loamy sands, with occasional fragments of Trap and Culm grit.

The evidences of denudation of Trap and associated sandstone furnished by the fragments in some of the above sections, are by no means exceptional in the breccias overlying the Trap rocks in Sheet 325.

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* Quart. Journ. Geol. Soc., vol. xlviii. (1892), p. 506.

Between Cowick and Alphington, breccia of small generally angular fragments of Culm rocks in red sand and loam, was observed.

By the road to Alphington, north of Lower Shillingford (Shillingford Abbot on the old map), red breccia of small fragments of Culm, trap, and granitoid rock in a loamy matrix was noticed; indications of bedding are shown by comparatively stoneless seams and lines of smaller stones. Near the above at Barton dark red breccia with grey streaks contains numerous fragments, mostly of Culm rocks in a sandy and loamy matrix. Another exposure in the same neighbourhood displayed red loamy breccia with grey streaks, containing occasional rather large pieces of grit and of granitoid rock with Murchisonite in rather small gravel, locally black stained (probably by manganese).

Near Peamore House red rubbly breccia, mottled with grey streaks, was exposed by the high road. The rock is almost entirely composed of small fragments, in places so small as to present the appearance of coarse sand.

In the little wood at about half-a-mile south of Old Matford, a large quarry exposed breccia of small angular and sub-angular grit and igneous stones closely packed in a red sandstone matrix. In the upper part the beds are thin and rubbly, but lower down they average about 2½ feet in thickness, although the bedding-planes are not always clearly defined. The dip is easterly, at about 12°, apparently. The Exminster sandstone is evidently faulted against breccia on the east, as the breccia exposed to a depth of about 100 feet in a large mural-faced quarry by the alluvium, has a south-easterly dip of 5°. In this fine quarry the rock resembles the Heavitree breccia; it occurs in thick beds containing numerous fragments of igneous rocks, including pieces of Murchisonite. The deep red colour is relieved by occasional grey and yellowish bands throughout the mass. Breccia has also been quarried at a quarter of a mile south-west of the Asylum.

At about half-a-mile or more south-west of Exminster Church rubbly breccia was exposed in a lane section. The rock consists of angular and sub-angular fragments of granitoid, grit, and trap rocks in a red sandstone matrix, roughly laminated. A quarry at 14 chains S. by W. from Exminster Church showed hard breccia, rubbly at the top, but thick and even bedded below, dipping in a north-easterly direction at 6°. The contained fragments are small and of average size consisting of purplish and grey grit, granitoid, and trap rocks. At 24 chains south of Exminster Church a quarry showed breccia of small and averaged-sized angular and sub-angular stones of grit, granitoid, and trap rocks in a red sandstone matrix. The beds average from 6 to 16 inches in thickness. The thicker beds were quarried out in large blocks for building-purposes. The dip is north-north-easterly at an angle of about 5°.

The Exminster sandstone and the patch north of it appear to be outliers. By the high road at Place Farm (Finches, on the old map), red rock sand in places brecciated and false bedded, and buff sand were exposed. The false bedding is marked by seams of concretionary sandstone. Opposite the gate to the Asylum, false bedded buff sand with bands of brown ferruginous sandstone was exposed in a pit. A little north of the sand pit a section by the high road exhibited yellowish grey and buff banded sand (recalling sands of Corbons rock, near Torquay), overlain by and giving place to laminated buff sand with brown ferruginous staining.

By the lane on the north of Exminster Church, red laminated sandstone afforded a north-easterly dip of 25° in proximity to its faulted junction with the breccia on the east, in which the quarry 100 feet high is situated.

South of Exminster the relations of breccia and sandstone are indefinite. Faults are evidently numerous, but few of them can be satisfactorily traced. There can be no doubt as to the local passage of the one rock into the other, but as shown on the map the position of the boundaries indicates outliers of breccia on sandstone in places, whilst as a whole the breccia underlies the sandstones on the east of it. This complication is doubtless due to the more or less marginal character of the coarser rock causing an irregular outward extension or dovetailing of sand and breccia, which is further exemplified in the Bradninch and Silverton districts.

A fault was evidenced in the lane section from 8 to 12 feet in height, near the turning to Crablake Farm. Laminated loamy sand rock with impersistent concretionary veins and strips of black ironstone (pan) is faulted against false bedded rock sand. This fault is probably prolonged to Luccombs Farm on the west. The extension of the strip of breccia on the north of Crablake Farm between converging faults to the alluvium is doubtful. At about half-way between Crablake Farm and Exminster, red and orange sand rock seems to pass into the breccia.

Throughout the area south of Exeter dips vary in amount and direction, so that no estimate as to the thickness of the breccia and sandstone is reliable, and the higher angles of dip are no doubt due in the majority of cases to faults which cannot be traced in homogeneous strata. The coast section between Clerk Rock and Langstone Point shows the interchangeable character of the breccias and sandstones and the frequency of faults.

2. *Exeter District.*

On crossing the alluvium of the Exe we encounter a district in which the character of the breccia is less stable than in that described above, and the sandstones concealed by alluvium east of Exminster are well developed. The sandstone and breccia of Exminster are continued northward toward Pinhoe, but at Whipton and in the northern parts of Exeter the breccia is replaced by brecciated clays, loam, and sands. The harder breccia crops out by the banks of the Exe near Newport House beneath old river gravel, its very sinuous junction with the overlying sandstones is probably due to some amount of horizontal replacement, or irregular eastward extension of the stones in the sandstones, so that this line has a general but not an absolute stratigraphical value.

By the high road from Topsham to Exeter, behind a house (the Northbrook Inn on the old map) north of Higher Wear, a section exposed brecciated loamy sand upon dark red loamy clay, mottled greenish, and interbedded with rock sands exhibiting false lamination. East of the above at New Court the sandstones pass irregularly into breccia on the north. The breccia is represented by loam and sand, with small sub-angular fragments of grit.

Between Heavitree and the Asylum, east of South Wonford, a lane-section disclosed the junction. Thick beds of red sand rock, intercalated with brownish red loamy sand full of small sub-angular grit stones, rest on consolidated breccia.

In the Exmouth branch railway cutting near Hill Barton the upper beds of the breccia, exposed to a thickness of about 30 feet, consist of red loam full of small angular pieces of shale and grit, with impersistent consolidated beds of breccia and lenticular bands of red and grey sandstone.

On the north of the high road at East Wonford a large quarry showed breccia of sub-angular grit fragments in a red sandstone matrix, with intercalated beds of nearly pure sandstone averaging from 8 to 9 inches in thickness. In the large quarries on the south of the high road the beds average from 1 to 3 feet in thickness, and seem to dip E. 40° S. at an angle of 12°. Some beds are nearly pure sandstone, others red sandstone closely brecciated with angular and sub-angular fragments of grit, quartz and igneous rocks (some containing Murchisonite) for the most part small. Impersistent veins of red and grey sandstone are visible in places vertically intersecting the beds, and may be due to the infilling of drying cracks in the breccia by overlying sands. These are the Heavitree quarries described by Dr. J. F. Berger* as "a quarter of a mile in length," and worked "to the depth of about ninety or a hundred feet." "The strata are from six to eight feet in thickness, and dip S.E., at an angle of about 15°." The greater hardness of the brecciated beds as compared with the more friable intercalated sandstones is noted. The contained fragments are described as "sometimes rolled and rounded, sometimes pointed with sharp angles, from very minute grains to the size of several inches in diameter. There are found in it rhomboidal crystals of calcareous spar and crystals of felspar [Murchisonite], most frequently of an opaque white, and decomposed; pieces of flint [Culm chert]; grauwacke [Culm grit]; yellowish limestone [Culm limestone?]; rolled masses of a species of porphyry . . .; pieces of a rock . . . having the appearance of a porphyry, the base earthy, and including small grains of quartz, crystals of felspar, and pieces of bluish carbonate of lime; and a whitish tender steatite [? quartz porphyry], in small angular fragments."

Murchison† regarded the Heavitree breccias as Permian, a view which would embrace all the New Red rocks west of the Exe in that formation.

Consolidated rubbly breccia with grit and igneous fragments, the former predominating, forms a mural cliff by the Exe at the boathouse and docks west of St. Leonard's Church. The dip seems to be in a southerly direction at about 5°.

The Heavitree breccia degenerates into brecciated clay and loam toward Whipton, and the clays, sands, loams, and brecciated clay and loam of Heavitree and St. Sidwell's parishes seem to underlie them. In these argillaceous materials there are several brickyards.

In a brickyard about half a mile N.W. of the East Wonford Quarries, at a place called Montle Grand on the old map, the pits furnished exposures of dark-red clay with irregular grey mottling, for the most part closely brecciated with small fragments of shale, and occasionally containing a few angular and sub-angular pieces of grit. In Mr. Hancock's brickyard near Clifton Road the pits showed red loamy clay mottled with greenish grey streaks and spots, and brecciated with small shale fragments, amongst which a few comparatively large pieces of grit and limestone occasionally occur. Some impersistent beds of red clay splitting somewhat cuboidally are intercalated in the brecciated clay. The brecciated clay from which the shale fragments are not extracted burns to a hard rough brick. Between the above and the Blackboy Road an adjacent brickyard afforded an extensive section of dark red loamy clay with one or two greyish bands, brecciated with small shale fragments, but here and there comparatively free from brecciation.

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* Trans. Geol. Soc., vol. i., p. 99. See also Conybeare and Phillips' Outlines of the Geology of England and Wales, 1822, p. 292.

† Siluria, 4th edition, 1867, p. 333.

By the old Tiverton road between St. Anne's Terrace and St. James Place, red sand was proved under dark-red marl capped by yellow and red clay. Dark red loamy clay with yellow grey sandy streaks and patches was observed by a new house between the L. and S.W.R. and the commencement of the Blackboy road.

By St. Sidwell's Street red sand was observed at the corner of Jeffreys Row and near York Street. On the opposite side of the street between Summerland Street and Verney Place red sand and brecciated clay were proved. Between York Street and Church Street red sand and marl were exposed. In Longbrook Street and by Barrack Road, near the Trap rock, red sand occurs. Between Queen Street station and Northbrook Park on the road to Topsham the strata appear to be for the most part covered by superficial gravels marking an old terrace of the Exe.

In a well in Bartholomew Street east of the Church breccia was encountered under the gravel. At the border of the gravel patch in Holloway Street, near Landsdown Terrace, brecciated clay and sand was exposed under the gravel. In South Wonford brecciated clay was observed in several places.

From observations in Queen Street the Northenhay Trap rests on Culm Measures, but whether the Longbrook Street and Barrack Road Sands overlie it, are faulted against, or pass under it is doubtful. In the Railway near Barrack Lane the Trap is probably faulted.

The railway cutting near St. James Road shows loamy sand and sandy loam, containing angular shale and grit stones with beds of red sand in the upper, and even bedded sandstone intercalated in the lower part of the cutting. Further on, toward the short tunnel at the Old Tiverton Road, the cutting exposes red loamy clay, brecciated with small shale fragments, containing beds of rock sand and sandstone. In Cross Lane, east of the old Tiverton Road, red loamy clay brecciated with small shale fragments was exposed. In the railway-cutting on the east of Cross Lane beds of red sandstone occur in brecciated red loamy clay, beneath which Culm shales crop out in one spot at the base of the cutting.

South of the Exmouth branch line by the stream south-west of Whipton an exposure, 15 feet in depth, showed thin bedded red greenish-mottled loamy clay occasionally brecciated with small shale fragments.

Between Whipton and Heavitree the rocks are of the same argillaceous character, more or less brecciated, and containing beds of sand or sandstone. In the small stream on the west side of Whipton, beds of breccia of angular grit and shale fragments in rather coarsely-laminated sand and sandy loam, gave a south-easterly dip of about 7°.

By the lane, north of Whipton, dark red, grey-mottled clay, in places brecciated with numerous shale fragments, was visible. East of Whipton the sands extend to about 10 or 12 chains from the Culm boundary, and the argillaceous beds intervening continue eastward to Monkerton.

The variable nature of the strata about Exeter renders the tracing of faults in them an impossibility, and the sinuosity of the sandstone boundary renders it extremely unlikely that the northerly attenuation of the breccia and brecciated clay is due to faults. In places where dips are procurable the dominant inclination is south-easterly. This makes it highly probable that the division between sandstone and breccia is here much more lithological than stratigraphical and that the breccias pass into sand and sandstone on the east.

We will now follow the sandstones from Monkerton southward to Topsham, and there crossing the Clist proceed northward to Clyst Honiton.

In the lane leading due S. from Monkerton to Gipsy Hill, a fine section was observed, consisting of red rock-sand slightly brecciated here and there, in places exhibiting false bedding and false lamination. South of Gipsy Hill the lane section exhibited pale buff grey-banded sand and reddish laminated sand. By the high road from Heavitree to Clyst Honiton, on the west of the third milestone, bright red sand-rock was exposed ; veins of dark purple ironstone (pan) occur irregularly and somewhat fantastically throughout. By the lane from the third milestone to Sowton pale red and greyish laminated rock-sand contains flat layers of ironstone, and in places shows false-bedding. By the Exmouth Branch line on the south of the high road from Bishops Clyst to Heavitree a quarry exposed orange-red false-bedded sand, making a brown sandy soil. By the high road, at about a quarter of a mile north-west of the above the sand is locally brecciated, and further on contains clayey seams or beds. Between the railway and Sandy Gate another quarry in rock-sand was opened by the high road. By the road from Sandy Gate to Topsham, north of the turning to Newcourt Barton, the sandstones make a blackish and reddish soil, and contain flat pieces of dark ironstone (pan). Mr. T. Andrew* described some remarkable tube-like ironstone pipes in a sandpit 2½ miles from Exeter in this neighbourhood.

The upper beds of the sandstone emerge from beneath the overlying marls at Woodbury Road Station, whence to Clyst Honiton their boundary can be traced without much difficulty. In the valley east of Woodbury Road Station sandstones occur at Exton and Woodbury Salterton, where they occupy a large tract and bear two outliers of marl; a small patch of sandstone is also present on the north side of the alluvium at the mill between the two places mentioned. It is quite possible that these patches (as well as some of the others, which are found in the Marl area), may represent the upper beds of the underlying sandstones, and not occur as local intercalations in the Marls. If this is the case the alluvium of the tributary valley conceals a fault bringing them up on the north.

The local occurrence of breccia in the upper part of the sandstones was observed in the following places:—

At the bend in the lane, west of Ebford, near the Alluvium, red rock-sand is brecciated in places with small grit stones. By the lane, on the west of Clyst St. George, a bed of breccia, of small sub-angular grit stones in red sand-rock, rests on dark red false bedded sand-rock. Mr. Ormerod† notes "the soft conglomerate with Murchisonite seen about 4½ miles from Exeter, in a roadside cutting, near St. George's Clyst." By the high road, east of Bishops Clyst and north of Clyst St. Mary, a pit disclosed light red false-bedded sandstones, with occasional seams brecciated with angular fragments, some of which resemble pieces of Trap rocks. Ormerod also notes "soft red sandstone, in which a little Murchisonite in detached crystals is seen" in a cutting on the hill on the Sidmouth road at Bishops Clyst.

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* Trans. Dev. Assoc. for 1888, vol. xx., pp. 379-382. For occurrence of pan in the sands see also account of the City Asylum Well by same author. The well section is given in the Appendix.

† Quart. Journ. Geol. Soc., vol. xxxi., 1875, p. 351.

West of Clyst St. George Church bright orange red sand was noticed in a ditch by the alluvium. South of Winslade House bright red rock-sand was exposed by farm buildings.

East of Sowton, by the lane south of Dymond's Farm, false laminated bright orange rock-sand was exposed. Red sands, with bands of black ironstone, near Clyst Honiton, presented an appearance of horizontal bedding. Ormerod mentioned detached Murchisonite crystals as occurring in soft sand, at Honiton Clyst.

At Hayes, by the high road, the sands seem to dip east at 5°, but as they are partly false-bedded their true dip is very doubtful.

At the fifth milestone, on the high road in proximity to the Marl junction, red sands have an apparent inclination of from 1° to 3°, in a south-westerly direction.

3. *Broad Clyst District.*

The prevalent clays in the north of Exeter are either faulted out, replaced by arenaceous materials, or conformably overlapped by sands at Pinhoe, clay being present in the south part of that village, whilst at Pinn Court (Langaton on the old map) red sands were exposed near the Culm boundary. Having regard to the obvious interchange in the relations of the sands and breccia and the local occurrence of the clays, the latter cannot be regarded as a stratigraphical horizon, so that local argillaceous developments such as those at Francis Court, south of Killerton, and near the mouth of the Crediton valley, west and south-west of Thorverton, are by no means necessarily on the same or on a corresponding horizon. The Broad Clyst district is characterised by the absence of breccia south of Killerton, by the constriction of outcrop of the Lower New Red rocks, and by their almost exclusive representation by sands and sandstones. To what extent this may be due to overlap on an irregular bed of the older rocks, and to faults it is impossible to say, but the irregularity of the old rock floor is clearly shown in the Culm inlier in the north of the district.

Dr. Shapter* has stated that "A quarry at Broadclist, half a mile to the north-east of the church, has yielded some specimens of ripple-marked stones, traces of annelids, the claw-like feet marks of two species of small crustaceans and obscure impressions of other objects (*Posidonia*)." The rock said to furnish the above is a red sand rock often exhibiting even shaly bedding.

The railway cutting at Mosshayne Farm (Motion on the old map) revealed red sands with seams of red clay. The patches of Trap rock at and north of West Clyst seem to rest directly on the intervening Culm inlier and to be overlain by sands. In the northerly patch of Trap, pipes or columns of sandstone indicate the infilling of cooling cracks in the lava during the subsequent accumulation of sands over it. In the south part of Poltimore Park (between Pit and Worsley farms on the old map) a stream section exposed red clay mottled with occasional buff patches, apparently associated with beds of sandstone and nodular slabs of ironstone. From here by Hornhill Farm (Franklin on the old map) for some distance toward Bampford Lodge the Culm junction is obscured by rainwash and gravelly débris. Behind some houses near Kerswell House a section disclosed red sand, stained blackish from manganese, with veins of black ironstone (pan), and false-bedded in places, under a superficial deposit of clay and loam with pebbles, 3 to 4 feet thick. Between Burrow, Black Dog, and Southern Lake is a tract called "Broadclist Heath" on the old map. In the southern part of this tract shallow pits exposed red, yellowish and whitish sands; the red sands exhibited the coarsest grain, and their particles were well worn. Where a windmill stood the sand is re-deposited, of a uniform red colour, and it contains gravelly débris (the gravel patch on the map).

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* Climate of South East Devon, p. 87.

On the south side of the Trap at Wishford Farm (Fishford on the old map) red and brownish laminated sandstones dip southward at 13°. On the north of the eruptive rock a quarry exposed flaggy beds and evenly laminated red, brownish and blackish sandstones, with southerly dips ranging from 20° to 43°. The grains are coarse, rounded, and for the most part composed of quartz. By the lane from Wishford Farm to the other Trap patch (on the map) red and blackish laminated sandstones and rock sand containing black ironstone (pan) are probably in faulted relation to the Trap. It is probable that the high dips in the sandstones are due to a fault.

At about a quarter of a mile east of Poltimore a large quarry, said to have been worked to a depth of 100 feet from the surface, exposed evenly laminated brown and blackish rock-sand on brown and reddish sandstone in layers averaging 2 inches thick in the upper 4 feet, 3 to 7 inches in the next 5 feet, and below that attaining to a foot in thickness. A workman stated that the bottom beds were thick,and had been used in the construction of bridges over the London and South Western Railway, as the rock hardens on exposure. The upper beds are used for hedging, etc. The surfaces of the laminæ in the brown and blackish rock are stained red. The dip appeared to be N. 40° W. at an angle of 17°. Unless the planes are due to false bedding on a large scale, it appears probable that the high dip is due to the proximity of a fault.

The relations of the Trap rock to the sands at Bampford Lodge are very obscure, and the former may be faulted against the Culm Measures, but on the north it is very probable that the Trap and Culm rocks are cut off by an east and west fault against the sands, which, at the northern end of Poltimore dip south at an angle of 7°. Such a fault prolonged eastward would account for the high dip in the quarry east of Poltimore, and is shown on the old geological survey map. By the road south of Ratsloe (Hatchleigh on the old map) beds of rock-sand were exposed near the Culm junction, dipping north at 5°.

By the road from Ratsloe to Huxham, and also to the north of Ratsloe, red and orange rock-sands were exposed. North of Ratsloe, and east of Russell's Farm (Russels Stars on the old map), a lane section disclosed light red rock-sand with blackish seams, in very regular laminæ, occasionally displaying false lamination.

In the tract called Lower Down on the old map, south of Danes Wood pieces of hard brownish ferruginous sandstone are scattered over blackish sandy soil, and in a lane (not shown on the map) red rock-sand was exposed. The low ground between Killerton and Danes Wood, Columbjohn and Francis Court, seems to consist of an admixture of red sand, loam and clay with gravelly patches.

At present confining our attention to the sands, we will return to Broad Clyst. By the High road south of Broad Clyst, false-bedded red rock-sand was exposed, and blackish bands follow the lines of false-bedding. South-east of Broad Clyst in the lane by Lake House, laminated and false-bedded rock-sands were exposed, the laminæ being roughly coincident with the surface contour. By the lane to Burrow on the east of Broad Clyst, false-bedded red rock-sands have an apparent dip in a northerly direction at 5°.

North of Broad Clyst, by the turning to Beaumam (Limbury on the old map), false-bedded sands have a southerly dip. Near Beaumam, clayey seams are probably intercalated in the sands.

At Burrow Farm, the lane cutting exhibited laminated red rock-sand. To the north, a quarry by the lane showed a bed of dark red grey-mottled marly clay in red laminated sands with blackish bands; near this a southerly dip of 5° was obtained. East of Burrow, by the road south of

Newlands, there may be a brecciated bed associated with marl and sand below the gravel patch on the map. Sand also appears to occur in the lower part of the marls at Laxbrook.

On the south margin of the Culm inlier, east of the above, unless the Clyst valley is along a line of fault with downthrow to south, the representation of the Lower New Red Rocks is wholly inadequate. The broken line on the map by Trow Farm, Little Barton Farm, and Hills Farm to Marsh Farm, near Clyst Hydon, has been drawn to admit a replacement of the upper part of the sands by clayey and loamy beds, but as far as the surface evidence goes this is very uncertain, and between Ashclyst and Trow Farms the clays are more probably referable to the overlying Lower Marls.

At Ashclyst Farm the following section of the uppermost beds of the sands was exposed. The beds are given in descending order:—

Fine grained red sand - - - - - - -	1 foot thick.
Stiff red and purplish brown clay with small grit stones in places - - - - - - - -	5 inches.
Fine grained red sand with occasional blackish streaks - - - - - - - - - - -	11 inches.
Light red dry sand - - - - - - - -	6 inches.
Fine grained red sand - - - - - - -	2 feet.

The alluvium of the Clyst and tributary streams conceals the connection of the above with the patch of sand at Westwood (Quicks on the old map) and at Clyst St. Lawrence; in both these places the sands rest directly on the Culm rocks. The Clyst St. Lawrence sands were exposed near the Church: they appear to be cut off by a fault against Culm measures on the north at Scorlinch Farm (College Farm on the old map). The next patch of sandstone on the border of the Culm inlier occurs at Clyst Hydon, red sand was exposed in the westernmost part of the village, the major part being apparently built on red clay. To the west of Clyst Hydon a small outlier of sand rests on the Culm Measures (at Wood on the old map).

At Woodhayes, near the above at a rather higher level, gravels rest directly on the Culm Measures. These gravels consist of angular, sub-angular, and well worn stones of Culm grit, shale and quartz in a matrix of red, reddish brown and brown earthy sand. They are evidently marginal accumulations of the New Red series, and are found mantling over the Culm Measures near the borders of the series, and occurring as outliers on the summits in the districts between Bradninch and Tiverton, and on the north of the Tiverton Valley. From Langford to Pottshayes these gravels conceal the northern slopes of the inlier; west of Roach Farm, at Whitedown Copse, Paradise Copse, and at Hoop Farm they cover the summit, which is in places over 500 feet in height. In the deep valley, on the north of Side Down, the Culm Measures are bounded on the north by red sandy loam with beds of sand and patches of gravelly loam, which underlie the gravels on the north, and probably pass into them by intercalation and dovetailing.

De la Beche * speaks of a considerable east and west fault that can be "readily traced at Spraydowns and Bere, near Killerton Park, where the carbonaceous series is brought into vertical

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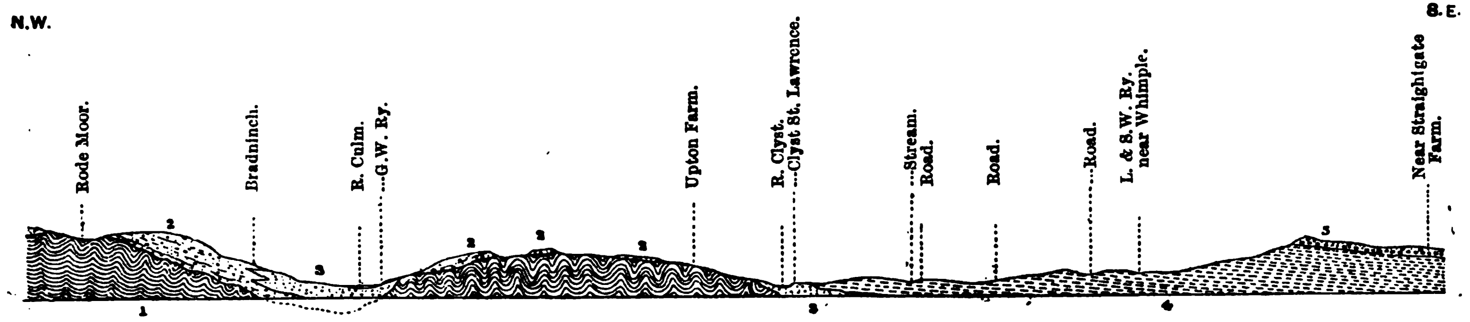
* Report on the Geology, etc., pp. 294 and 312.

Fig. 5.—*Section from near Bradninch to Whimple.*



New Red Sandstone Series
- 5. Pebble Beds.
- 4. Lower Marls.
- 3. Lower Sandstone.
- 2. Breccia.

1. Culm Measures.

ontact with red sandstone." This passage is rather ambiguous as Bere (Beare on the new map) is more than half a mile north of Spray Down (Sprydon Plantation on new map), and could not therefore be in line with an east and west fault between Culm and New Red rocks. Assuming that the straight Culm boundary at Scorlinch Farm is a fault which in its westerly prolongation separates the Culm of Side Down from the New Red rocks on the north, it would have a downthrow to the south at Scorlinch Farm, a downthrow to the north at Side Down, and would have little apparent effect on the sands and Traps on the west of Spray Down, although the latter case ceases to be an objection owing to the occurrence of nearly north and south faults on the west of Spray Down.

A lane at about half a mile south of Sprydoncote (Spraydown House on the old map) afforded a stream section in red laminated loamy sand-rock apparently dipping westward. Near the base of the adjacent hill of Trap altered sandstones crop out evidently from beneath the Trap. Between Sprydoncote and Dolbury (Crab Tree on the old map) the patch of Trap exhibited no definite relation to the sands and loamy and gravelly beds surrounding it. It might be intrusive in them or they might overlie it.

In the chapter on the Trap rocks sections are given showing their relations to the surrounding New Red strata where visible. To avoid recapitulation as much as possible it will be sufficient to state here that the Killerton Traps, although they may conceal a vent, seem to rest on the surrounding sands which contain clayey seams and an admixture of gravelly loam. A section illustrating the unstable character of the rock was exposed by the high road east of Killerton at a few chains south of Dolbury. The exposure, 10 feet in height, showed the succession given in Fig. 6, p. 32, under an irregular patch of minette (5).

At 15 yards from this spot a good-sized block of trap (minette) occurs in the gravelly loam (4).

In the road from Budlake to Hollis Head the gravels bounding the Culm Measures seem to overlie a small patch of Trap which rests on blackish sands containing gravelly beds and is succeeded by red clays and loam : the junction of Trap and underlying sands is repeated by step faults in two places.

These associations of clay, loam and gravel with the sands occurring in the flat clayey and loamy tract between Francis Court, Columbjohn and Killerton, on the one side, and the sands, clays, and loams underlying the gravels on the north of Side Downs on the other, favour the probability of an argillaceous replacement of the upper beds of the Sand series on the south and east of the Culm inlier.

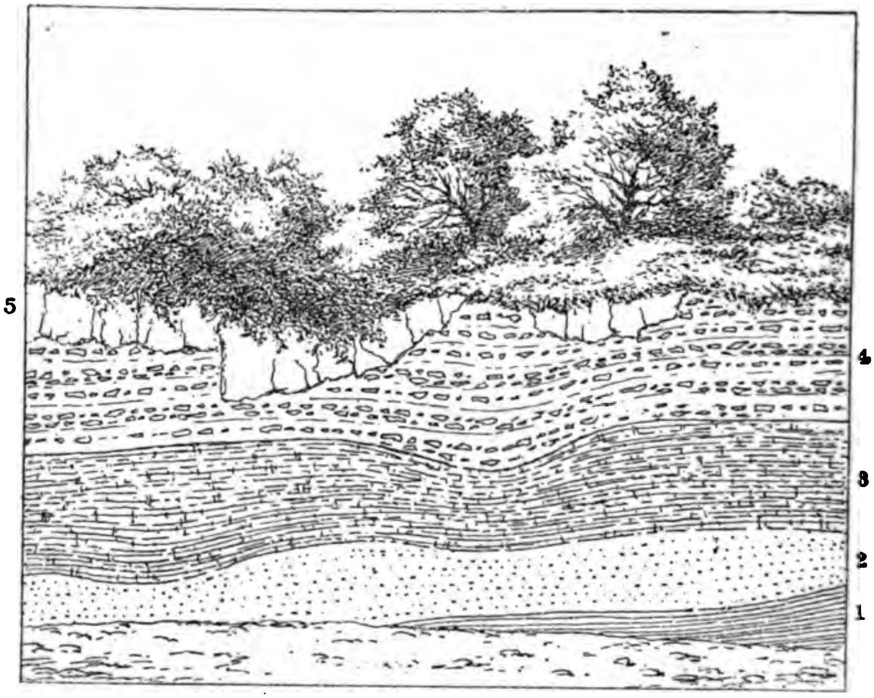
A quarry in Trap by the high road south of Beare shows sands with trap fragments at base resting on Trap. The Trap seems to be cut off by a fault throwing the New Red rocks down on the west.

North of this quarry, near Beare a section by the high road showed hard beds of sandstone upon gravel of grit fragments dipping sharply toward a mass of gravelly breccia against which they seem to have been thrown by a fault, where the section was unfortunately concealed. This may be the fault mentioned by De la Beche in passage cited above (p. 29), as its easterly prolongation would cut off the narrow band of Culm Measures near Beare—but its further effects are lost on entering the gravelly New Red tract of White Down Copse. There may be a fault between Beare and Whiteheathfield Barton cutting off Culm Measures on the west, probably against loam, clay, and sand on the low tract flanking the alluvium of the River Culm, where no reliable evidence was obtainable. On the south of Garnshayes Farm (at Turners-hayes Farm on the old map.)

and at and south of Langford sands pass irregularly upward into breccia and gravel. At Langford red rock-sands with a blackish band (14 inches thick) were seen. The sands probably pass into loamy and clayey beds toward Langford Court.

Sands were visible at Garnshayes Farm, at the farm half a mile east of it, and at a farmstead (named Lower Bullaller on the old map), S.E, of Bulealler Ho, but the surface evidence indicates loamy clay and loam elsewhere, until we come to Westcott and Bulealler Ho, where red sands associated with loam and clay pass into and under gravel of well worn and sub-angular grit and quartz stones in bright red loam and clay. At Westcott the gravel gives place to red brecciated sand, which seems to rest on and give place to red sand in the lane on the east of Westcott; these materials rest on Culm Measures at the north margin of the map. It is probable that a clayey replacement of the upper beds of the Sand and Breccia series has taken place east of Westcott.

FIG. 6.—*Section south of Dolbury, near Killerton.* (See p. 31.)



5. Minette.
4. Red gravelly loam with irregular grey streaks.
3. Red grey mottled clay splitting in small cuboidal pieces.
2. Red loamy sand.
1. Red clay (like No. 3).

4. *Bradninch and Silverton District.*

On the north margin of Sheet 325, between the Exe and Culm New Red gravels bound the Culm rocks, rising to heights of from 700 to over 800 feet on their summit levels, and overlapping the finer sands, loam, and clay deposits which are exposed in valleys cut through the gravels between the towns of Bradninch and Silverton. These latter are probably connected under the alluvium of the River Culm with the sands that pass up into the gravels of Westcott.

By the high road at Bowhill Farm, north of Bradninch, the gravels are composed of well worn, sub-angular and, less frequently, angular Culm grit stones of various sizes in reddish earthy sand, betraying but slight signs of stratification. Nearer Bradninch intercalations of finer materials indicate bedding. The section in downward succession is as follows :—

4. Gravel and breccia of well worn and sub-angular grit and quartz stones in a coarse red sand matrix, with a thin impersistent strip of finer sand.
3. Thick bed of red loamy clay, splitting in cuboidal pieces, and passing into red rock-sand showing false lamination, and containing impersistent seams of fine grit gravel.
2. Thick bed of gravelly breccia, with well worn and sub-angular stones in a red sand matrix.
1. Sandy loam about 20 feet thick, passing downward into gravel.

From Kensham Mills northward, for a mile, the alluvium is bounded by gravels, apparently forming a river terrace of redeposited New Red gravel.

The New Red gravels as we proceed southward from their junction with the Culm Measures give place to breccia and brecciated sands, which seem to underlie them, and these in their turn overlie and probably pass horizontally and irregularly into the sands and loams which occupy the valleys at Bradninch, Silverton and the intervening district. The change from gravel to breccia is sufficiently marked to have suggested a separation during the survey of the district in 1872.

This separating line is shown on the map, although subsequent investigations proved that the gravels were actually marginal deposits of the New Red, and not accumulations of a subsequent period, as was first thought probable. The line in question follows the 400 feet contour, more or less, from Bowhill Farm westward, descending to the Exe valley at half a mile south of Chitterley.

By the road west of Bradninch, at about three-quarters of a mile south of Downs, a good section was exposed consisting of coarse and fine red rock-sand, brecciated with angular, sub-angular, and worn grit stones, seldom large. Bedding is well shown by the linear distribution of the coarser and finer materials, which in the high road on the south gave a westerly dip of 5°.

The sands in the valleys at and near Bradninch were not clearly exposed. In the road on the east of the lane to Moorland red loamy sand was exposed under gravelly clay. Near Hele Payne red loamy sand was exposed under breccia. The sand in the Greenslinch and Quantishaies (Gransleigh and Casebury in the old map) valleys seems to be associated with loam and clay; red clay being exposed in two places between Moorland and Greenslinch.

At Hele the breccia is a reddish brown gravel of sub-angular grit, and occasionally quartz stones in sand, apparently dipping toward the east at 15°. Near its western margin a south-westerly dip of 13° was obtained in this mass of breccia.

The railway cutting between Hele and Silverton Stations shows 20 feet of red rock-sand with a tendency to lamination. The junction with the breccia north of the cutting is covered by superficial deposits, but sand was exposed at Worth.

A quarry in the Silverton Park breccia gave a southerly dip of 15° in reddish brown, greenish mottled sand, with occasional greenish streaks brecciated with sub-angular and a few well-worn grit and, less frequently, quartz stones; further south the breccia seems to pass into or under brown earthy gravel with patches of red loam, giving place to sand near Silverton Station. It is probable that the earthy gravel may be a superficial deposit.

A small patch of Trap, cut off by fault on the north, dips under New Red sands, partly brecciated, in an old quarry near Silverton Park House. Between Silverton Park and Red Cross the road has been cut 12 feet deep in gravelly breccia, consisting of numerous fragments of grit and shale, mostly small, in red earthy sand, apparently faulted against red and blackish sand-rock with brecciated seams of small fragments. At Red Cross the breccia somewhat resembles cob (adobe), the mud formerly largely used for building outhouses, etc. Near Red Cross on the south red sands, with bands of breccia, were seen dipping south under a patch of Trap. The Trap was visible for 6 chains by the road, but in this distance its junction with the underlying sand is twice repeated by faults. South of the Trap red sand and gravelly sand and loam occur. Angular fragments of pale pink chert occur here and there in the breccia between Red Cross and Silverton By the road from Silverton toward the Inn near Rudway (Roughfield Inn on the old map) the breccias, unless faulted down, would appear to dip under sands southward, and the sands in their turn to pass under the Trap east of the Inn. The section showed breccia of small shale fragments with beds of loamy sand, which near Silverton gives place to a dense gravel of angular and sub-angular fragments in reddish-brown loam.

Between Up Exe and Silverton the breccia is of a gravelly character containing grit and quartz stones. The Silverton Trap was shown in an exposure in the south part of the village resting on a bed of sand on breccia with grit and quartz stones. It is longitudinally intersected by a fault, which partly bounds it on either side. The Trap patches near Stumpy Cross seem to be Outliers, the westernmost patch near the Rudway Inn overlies sand on the south, which was seen dipping north. In the lane south of Poundsland the Trap at the Mill rests on red rather loamy sand, upon reddish brown gravel of well-worn and sub-angular brown grit, and quartz stones, occasionally rather large, in an earthy matrix. Towards Poundsland the continuity of the gravel is broken by a mass of red loamy sand imperfectly exposed, and either a faulted repetition of the beds underlying the Trap or intercalated in the gravel.

Hazel Barton on the old map is called Old Heazville Farm on the new map, and Rew Mill on the old map is called Hazel Barton on the new. The large Trap mass near these places was exposed in a quarry at its western extremity, and red and blackish sand was visible on the north side. At Old Heazville Farm coarse reddish brown sand dipping S.E. at 12° is either faulted against the Trap or overlies it.

From the above observations it seems extremely probable that the eruptive rocks of Stumpy Cross and Heazville are on the same horizon, and that the intervening New Red strata lie below and are kept at the surface through undulations and perhaps repeating faults. As far as the imperfect nature of the surface evidence permitted one to judge the rocks consist of sand, loam, and clay. If, as appears highly probable, the Silverton and Killerton Traps are contemporaneous emanations from a local source or sources there is no reason for excluding the Traps of Poltimore, West Clyst, and Fishford farms from the same category, and this would indicate vulcanicity in the Lower New Red beds at a much later date in their accumulation than the emission of the Traps of Exeter and Dunchideock.

In the road from Stumpy Cross to Silverton nearly horizontal beds of brownish, locally red, loam containing small stones were seen resting on an uneven surface of breccia with numerous angular and sub-angular grit stones, seldom large, in reddish sand which also occurs in strips in the breccia, and with the distribution of the fragments gives a southerly dip of 25°. This appearance of unconformity may be due to a comparatively recent reassortment and redeposition of the materials of the New Red.

The high dips of the breccia south of Silverton are probably due to faults. Faults cannot be traced in the Bradninch district owing to the evidently unstable character of the rocks, nor can the boundaries of sand and breccia be relied on as definite lines, but rather as a general lithological distinction which may have local stratigraphical value.

Sand-rock is exposed on the margin of the river gravels near Rewe, but these superficial deposits hide the connection between the New Red rocks on either side of the Exe.

5. *Crediton District.*

In the area west of the Exe we find all the types of the Lower New Red rocks in the districts already described. Between Thorverton, Shobrooke and Brampford Speke we have sands, loam, clay, and brecciated clay, north of Thorverton gravels of the Bradninch type, and about Crediton and Newton St. Cyres breccias of the Exminster and Dunchideock type.

The river cliff at Brampford Speke is composed of distinctly bedded rock sand or sandstone, which, at the footbridge over the Exe, dips north at 20°. Opposite Nether Exe the sandstones have a southerly dip of 13°. South of Brampford Speke near the Culm Measure boundary red rock-sands appear to dip in an easterly direction at 10°. Sands were exposed by the lanes west and north-west of Brampford Speke and in pits on either side of the road at Three Barrows north of Upton Pyne.

Near the Culm Measure boundary at Upton Pyne Church red and blackish sand was exposed in a pit. A pit was sunk for manganese ore* to a depth of 25 feet on the west of the church in rubbly blackish brecciated sandstone, which was also exposed at Langford. At Bidwell Barton sands occur. On the east of Winscott Barton red sands were exposed.

On the north of Upton Pyne and north of Brampford Speke at the road junction east of Willowpark the sands contain intercalated beds of loam and clay. Between Berrysbridge and Newton St. Cyres Station the sands are associated with loam and clay, occasionally containing coarse sandy or brecciated seams. At Nettacott a southerly dip of 12° was obtained in them.

At Inner Norton sandy and loamy beds, brecciated in places, dip south at 10°.

At Wyke (Week Farm on the old map) red loamy sand passes down into breccia of small stones and coarse sand, and is intercalated with it. A southerly dip of 7° was obtained. At the Mills, where fine dark red breccia associated with coarse sand mottled with grey stripes is exposed, a southerly dip of 8° was observed, and at Creedy Barton a south-south-east dip of 6° in fine breccia and coarse sand. Sand was exposed at the cross roads south of Shute, and further east at the turning to Downs and Yendacott Farms, where there is a southerly dip of 14°.

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* See Conybeare and Phillips' Geol. England and Wales, p. 296.

At Efford hard beds of breccia and red laminated sands were exposed: the sand might be a faulted repetition of the sand at Shute: in both places the breccia furnished southerly dips of 10°.

North and east of Efford and Yendacott the breccia is mostly represented by brecciated loam and clay. At West Raddon, Uppingcott, and the cross roads near the latter (Raddon Cross on the old map) breccia of small shale and grit fragments in sand and loam is intercalated with purplish red loamy clay: here southerly dips were obtained. These associations strongly resemble the strata in the northern part of Exeter and between Heavitree and Whipton.

Between Raddon Court and Lynch (Chapel Farm on the old map) there was an exposure of red rock-sand with loamy beds and soft red sandstones splitting in thick laminæ and occasionally containing brecciated seams. These sands and sandstones were shown passing under the Trap south of Lynch, the junction being apparently repeated by a fault bounding the strip of Trap west of Lynch. It is not improbable that this fault, prolonged in a north-easterly direction, accounts for the presence of a small patch of Trap north of Thorverton, which also rests on sands and is surrounded by gravel and breccia. The sand is mottled with large grey and buff patches and presents a banded appearance near contact with the Trap, it dips northward about 11°; the gravelly breccias between it and Courthayes dip in a similar direction at 8°.

Sands are occasionally visible between Berrysbridge and Thorverton, and in Thorverton. By the road from Yellowford to Thorverton an anticlinal undulation was noticed in beds of red loamy sand with intercalations of dark red loam, splitting in small cuboidal pieces. Under the superficial gravel south of Court Barton, a shallow pit revealed red clay partly brecciated with small shale fragments. On the east of Berrysbridge the sands contain clay beds. Sands are exposed in a Trap quarry west of Raddon overlying the Trap rock near its westerly termination. At Bidwell red sand with clayey seams was exposed; it forms a patch on the margin of the alluvium of the Exe, possibly in faulted relation to the New Red gravels and Culm Measures on the north, or it may rest on the latter and be overlapped by the former. In either case these sands and clays are doubtless continuous, beneath the intervening river deposits, with the similar materials in the valleys near Silverton.

The New Red gravels on the north side of the Crediton Valley are derived from the Culm rocks on which they rest, and in character and composition are identical with the gravels bounding the Tiverton Valley with which their continuity is scarcely severed by denudation north of Bradninch in two or three places

Around Pitt, north of Bidwell, the gravels consist mainly of dark purplish grit stones, partially rounded, or merely bevelled at the edges, in a matrix of red earthy and sandy loam. Some of the stones are large, and exhibit smooth flat surfaces. In ploughed ground the surface stones have often the appearance of striation from scratching by the plough. At Cadbury the gravels are brownish, the stones not much worn, and the matrix earthy.

On the west of Cadbury in an outlier and on the east, north of Fursdon, the gravels attain summits of 800 feet. The road on the south side of Fursdon is cut in gravel of sub-angular grit stones of various sizes in red earthy sand and loam; the smaller stones sometimes present polished surfaces. In the valleys between Fursdon, Upcott, and Ashley the gravels seem to rest on reddish-brown sand with blackish bands, which is exposed in the road west of Upcott, but as the road for the most part furnishes evidence of gravel, either subjacent or a wash from higher ground, the sands may be merely a patch in the gravels.

Between Ashley and Terley (Leigh on the old map) a pit near the road furnished a gravel section with no apparent indication of bedding. The stones are for the most part of brown grit, varying in size from the dimension of a man's head to that of a pea. They are more or less worn; many present dark bronze-coloured polished surfaces. The matrix is reddish brown and earthy. Small angular fragments resembling indurated New Red sandstone were occasionally met with in the gravel, but as even shaly sandstones occur in the middle Culm Measures in places it is not safe to base any theory on the resemblance of these stones to sandstones indurated at contact with Trap. On Raddon Hills, south of Kidlake (West Bowley on the old map), the gravels contain very large fragments of grit similar to the Culm grits at Kidlake. The gravel on the high ground south of Stokeleigh Pomeroy is earthy, consisting of angular and sub-angular stones, very variable in size, chiefly brown grit, in brown and reddish-brown loam and loamy clay. At Coombe Barton the gravels are represented by red loamy sand, with small sub-angular and well-worn grit stones.

Between Thorverton and Shobrooke Lake the gravelly beds seem to underlie the sands and loam on their southern margin, but this does not necessarily indicate a general infraposition, for the marginal character of the gravel is so evident that its inosculation with, and replacement by, finer materials contemporaneously accumulating in deeper water is more than probable. The sands, clays, and loamy beds between Brampford Speke and Thorverton pass into brecciated sand, loam and clay on their strike westward, until on reaching Shobrooke Lake they appear to die out on either side of a central mass of breccia. From Shobrooke Lake westward sands can only be separated from the breccia in the vicinity of Trap patches. The abundance of stones of igneous rocks in the breccia to the west of Shobrooke Lake is very noticeable.

At Little Silver the breccia contains large unworn fragments of a pale grey rock, probably igneous, and is mottled with grey vertical and horizontal streaks. About Shobrooke large sub-angular fragments of igneous rock, unlike any exposed *in situ* in the area, are met with here and there in the breccia; the matrix varies from coarse loamy sand to sandy loam and loamy clay. Near the church the breccia is a fine gravel containing numerous fragments of Trap.

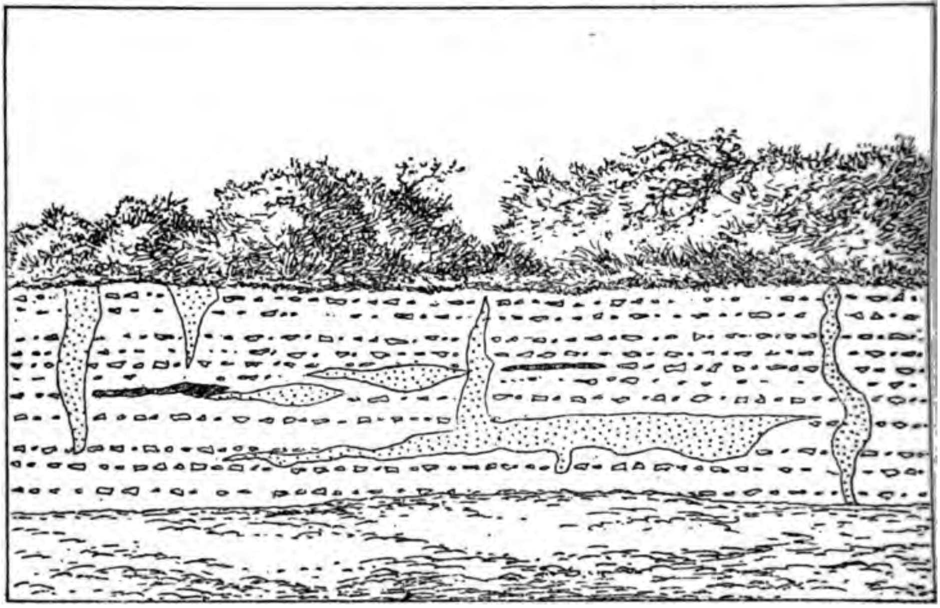
South of Haske the breccia consists of small angular and slightly-worn fragments of grit, igneous rocks, and of sandstone (apparently altered New Red). Bedding is indicated by alternations of fine gravel and coarse sand and by grey streaks, giving a southerly dip of from 3° to 5°. Toward Little Silver the breccia usually consists of small grit, quartz, and igneous rock fragments, almost angular, in a red loamy matrix. Near Haske, large fragments of igneous rock, generally much decomposed, occur in the breccia. To the north of Shobrooke Park and Bradley pebbles and sub-angular fragments of grit and quartz, the former sometimes large and presenting a polished appearance, are prevalent, but igneous rock fragments are locally abundant. The matrix varies from sand and sandy loam to loamy clay, and false-bedding is occasionally shown.

West of Newton St. Cyres the breccia consists of a dense dark red gravel of small angular and sub-angular stones of grit and igneous rocks.

The railway cutting near the Mills (Downs Mill on the old map) exposes red rubbly breccia, with strips and pockets of red sandy loam in places. The stones are rather small, angular and sub-angular, of grit and igneous rock, those of grit apparently predominating. South of the Mills a road cutting, 14 feet in height, exposed red gravelly breccia, containing igneous fragments generally of a dark grey colour; the stones do not exhibit any distinct indication of bedding. False laminated red sand occurs in irregular vertical and horizontal strips in the breccia, as shown in Fig. 7, also a band of black ironstone (pan).

Near Hookway the breccia contains small fragments of igneous rocks in sandy loam, bedding being indicated by bands of larger stones. The breccia near Rudge (Ridge Barton on the old map), forms a red gravelly loam with numerous igneous rock fragments. On the east of the farmhouses a southerly dip of 10° was taken. At about half a mile south from Crediton Station, the road section consists of red gravelly loam mottled with grey streaks, containing small angular and sub-angular grit and igneous rock fragments and nests or patches of larger stones here and there, amongst which a boulder of fine grained igneous or altered rock was noticed. Strips of sand occur irregularly in the breccia in part of the section, as shown in Fig 8.* Their distribution, as in the case previously figured, denotes a certain amount of contemporaneous erosion, or more properly the infilling by sand of cracks opened in the surface of the breccia during intervals in its deposition.

FIG. 7.—*Road-cutting south of the Mills between Crediton and Newton St. Cyres.*



New Red breccia with strips and pockets of sand and ironstone (black).

East of Yeoton (Uton phonetically) in the road section, the breccia consists of angular and sub-angular fragments of igneous and altered rocks and grit in red loam and clay, with grey streaks and impersistent indications of bedding. In places the appearance is rather that of an ancient talus than of a stratified deposit. South of Yeoton the breccia consists of angular and sub-angular grit and igneous rock fragments in a red loamy clay matrix. There is hardly any appearance of stratification. The grit stones frequently exhibit signs of alteration. The breccia overlies the Yeoton and Posbury Traps to which reference will be made later on. (See pp. 42, 72.)

Near Crediton, on the south and west, the breccia is usually represented by a more or less dense gravel of small angular and sub-angular fragments of igneous and altered rocks and grit, with occasional large boulders of igneous rock, some resembling elvans. In the lane at Park, west of Crediton Station, large unworn blocks of a fine-grained, pale pinky grey rock occur in it. A southerly dip of 5° was taken near Crediton Station. A similar dip was taken in the road to Crediton on the north of the turnings to Moorlake and Denbury.

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* The trees should not have been drawn in this sketch, p. 39, as there is only hedge-growth.

The lane cutting at Moorlake is from 15 to 20 feet in depth in red gravelly breccia, with bedding indicated by seams of larger stones and occasional grey streaks. Very large trap and altered New Red boulders were observed in it at 5 feet above the roadway, the latter boulders consisting of hard mottled sandstone.

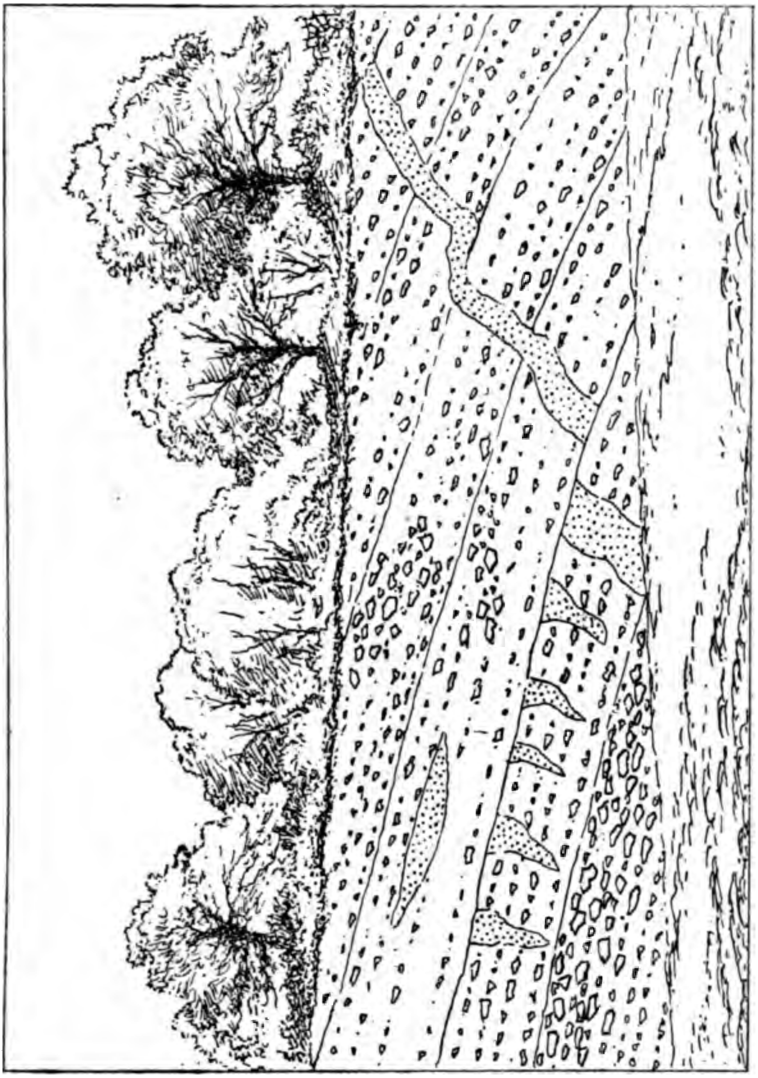

FIG. 8.—*Road-cutting half-a-mile south of Crediton Railway-station.*

New Red breccia with strips and pockets of sand.

West of Moorlake and south of Stairhill the lane cutting is from 10 to 20 feet in height in red and brownish earthy loam with numerous angular and sub-angular fragments of igneous and altered rocks and grit, most abundant along the bedding planes. Large stones of granitoid rocks occur in the breccia.

At the west end of Crediton, near Chapel Downs, breccia was exposed by the road to a depth of 15 feet. The rock consists of angular and sub-angular fragments of igneous rocks (including traps) and grit in red loam, bedding being indicated by alternations of coarse and fine materials and by grey streaks. An impersistent band of rather large stones was noticed, and large boulders are dispersed here and there throughout.

Near the Workhouse the breccia afforded a south-westerly dip of from 15° to 20° in one place, and in another grey bands gave an inclination of 10°. On the hill slope facing east, where the grey bands were noticed, they are bent over in the direction of the slope in the upper part of the exposure, a phenomenon due to the "run of the hill" analogous to the bending over of outcropping slates in the older rocks toward the valleys on the sides of which they occur.

By the high road from Chapel Downs toward's Spencecombe the rocks seem to consist of red loamy breccia with igneous and grit stones. The lane section toward Jews Hollacombe exposed from 10 to 30 feet of loose gravelly breccia chiefly derived from igneous rocks, for the most part small and with dark grey exterior. The matrix consists of the same materials comminuted. Bedding is shown by seams of the finer materials, by occasional impersistent strips of sand, and by alternations of brown, reddish brown, and blackish colours.

North-west of Hollacombe the breccia forms a rubbly gravel of angular and sub-angular stones, mostly small, of igneous rocks and grit in red loamy sand. Fragments of Murchisonite crystals are abundant.

Near Yeoford the breccia usually presents the appearance of a rubbly gravel rock of small sub-angular stones of igneous rocks and grit in a comminuted matrix of the same composition. By the north and south road west of Hollacombe the breccia contains numerous fragments of igneous rocks, and gave southerly dips of 5° and 8°. West of this road, near the head of the valley south of Combe House, grit stones often very slightly worn largely predominate in the breccia.

Between Hollacombe and Gunstone (Stockaday on the old map) the breccia consists of small fragments of igneous and altered rocks and grit in a sandy and earthy loam.

At the bends in the lane at Gunstone Trap rock was visible, inosculating with hard brown and blackish sandstone. An adjacent pit exposed reddish brown loam with fragments of trap; in one spot 6 feet of red earthy loam and sand containing fragments of the trap and indurated sandstone with blackish streaks. On the north of the Trap, breccia containing fragments of igneous and altered rocks dips south, and is probably faulted against it. The Gunston Trap was doubtless connected with that of Posbury and Yeoton, and rests on indurated sand-rock.

By the roads to Sandford and Creedy Bridge, near their junction north of Crediton, southerly dips of 8° were taken in the breccia. Just north of Crediton by the road to Long Barn the breccia consists of angular and sub-angular fragments of igneous and altered rocks and of quartz in a dark brown loam made up of flat grains of Culm shale.

The road from Pounds Hill (Forches on the old map) to Sandford has been cut to the depth of from 10 to 15 feet in breccia varying from a dense fine gravel to coarse sand with bands of larger stones and boulders of igneous rock here and there amongst which decomposed trap rock is noticeable. The breccia is composed of angular and sub-angular stones amongst which pieces of indurated sandstone and shale or claystone, cherty rock and quartzose grit predominate. In one place the breccia seems to pass abruptly into bright orange red sand. Strips of sand and loam occur here and there along planes of bedding or diagonally crossing them. In one spot a fault with a downthrow of 5 feet was detected through the displacement of a strip of sand, and there are no doubt many more small faults which have escaped detection. The dip on the whole seems to be south at an angle of 5°. Between Sandford and Venn the road section exposed alternations of red sandy loam and fine gravel of sub-angular and rounded stones with bands of fair sized grit stones. The section is mottled with grey streaks, generally along the bedding. The breccias of Sandford and Venn contain numerous small fragments of igneous rocks. Near Venn and in the south part of Sandford southerly dips of 15°

were obtained in the breccia, and at and near the westernmost houses of Sandford village southerly dips of 15° and 20° were taken, but if not fault dips these may indicate false-bedding. In the Sandford breccia a fragment was found with chalcedonic coating resembling the Beekite structure, so common in the Paignton breccias. Mr. Vicary had previously discovered Beekite structure in fragments in the breccia of North Tawton in the adjacent map on the west (Sheet 324).

Proceeding northward from Sandford and Venn toward the Culm Measure area, grit stones, often well worn, largely predominate in the breccia, as also on the north of West Sandford and near New Buildings, being the westerly continuation of the Bradninch New Red gravels.

North of Ruxford Barton the gravel consists of pebbles and sub-angular fragments of grit, giving place southward, in the road to Sandford, to coarse red earthy sand and fine red and buff breccia, intersected by grey streaks and with bands and patches of grit pebbles.

Between West Sandford and Ruxford Barton, faults were exposed in a lane cutting. In one spot red loamy sands with more consolidated bands, exhibiting a tendency to coarse lamination, and containing thin seams of red and grey clay and tough beds of yellowish fissile sand-rock, are obliquely thrown down against alternations of coarse and fine red and buff loamy sand containing small pebbles and sub-angular fragments of grit. Near this the section consists of coarse red earthy sand with grey streaks containing small pebbles and sub-angular stones of grit and quartz.

The sections west of Sandford may be generally described as irregularly associated fine breccia, loam and sand, with occasional beds or seams of larger stones and of marly clay; and they often exhibit false-bedding. On revisiting them in May, 1891, with Baron von Reinach, that geologist was struck with the exact resemblance of the rocks to the Messel type of the German Permian, a passage series from the Upper Sötern to the Wadern beds.

By the lane leading northward from West Sandford a fault, or instance of false-bedding, was exposed near the farmhouses. Tough, irregularly bedded sandstones, brecciated in places, are apparently let down against gravel of rounded grit stones in a coarse red sand matrix, dipping sharply toward the fault, or else strongly false-bedded. This gravel extends northward to the Culm Measures, and is also present north of the Trap patches near New Buildings.

South of New Buildings the sandy and loamy beds and grit gravels in the valleys are subjacent to the Traps, whilst the breccias with igneous fragments are for the most part of subsequent formation, but in the absence of Trap patches east of West Sandford it is impossible to say how far the gravelly New Red on the Culm margin may be regarded as inferior to the horizon of the Traps. The more intimate relations of the Traps are given with illustrations in the chapter on these rocks, it will suffice here to mention a few of the junctions.

At Woolsgroove (Wellsgrove on the old map) Farm the Trap rests on grey and buff sand and fine breccia, partly made up of triturated volcanic materials, which seem to overlie the grit gravels on the Culm margin.

Similar beds dip under the Trap at West Sandford. On the margin of the map south of the Trap near Spencecombe, N. and S. dips in the breccia indicate an anticlinal and the probable proximity of a fault. By the high road east of Spencecombe the breccia contains large boulders of porphyritic rock and of a pale pinkish grey rock here and there throughout the section bedding being indicated by alternations of coarse and fine materials and by grey streaks.

The larger Trap mass at Posbury proves the intercalation of sand between outflows of the lava, and in the section near Yeoton, Trap, under breccia with igneous fragments, rests on sandstone, as at Gunstone, and sand partly brecciated. The thickness of strata underlying the Trap may be over 50 feet.

From the above notes it seems reasonable to regard the Yeoton and Posbury Traps as synchronous with those of Spencecombe and New Buildings, and the mass of the breccia intervening as the result of denudation subsequent to the local volcanic episode, during which the lavas, and even the preexistent New Red Rocks altered by them, were extensively denuded.

There is therefore in the Crediton Valley a series of Secondary rocks older than the Traps, and a mass of breccia newer than them, which can be distinguished in the vicinity of the Trap patches, but not with any certainty elsewhere. The first impression of the structure of the Crediton Valley that would be suggested is that of a shallow synclinal with undulations, but the prevalent southerly dips do not favour this view. A dip of 5° S. in a distance of 2 miles would give a thickness of more than 900 feet, but any estimate is manifestly conjectural. The certainty of faults and the possibility of many of the comparatively high dips being on false and not true bedding render any estimate based on average angle of dip most untrustworthy.

Dips seem to indicate a synclinal structure, the axis crossing the Exe on the north of Brampford Speke and running toward the Culm boundary somewhere between Rudge and Newton St. Cyres; but it is not safe to attach any general significance to this owing to probabilities of faults and to the prevalence of false-bedding, and the same remark applies to most observations of dip recorded in the above notes.

LOWER MARLS.

The fine coast section as we proceed from Exmouth to Straight Point presents a series of Red Marls with intercalated thick and even beds of sandstone. These layers sometimes red and sometimes whitish strongly resemble in appearance parts of the Upper Bunter sandstones of Germany. The section is much cut up by faults rendering the absolute succession of the sandstone horizons doubtful. In comparison to the development of marl in which they occur the proportion of sandstone is small, and at Straight Point, where the maximum thickness is attained, a fault separates the beds from a fine cliff section of marls in which no thick sandstone occurs. These Marls seem to be at least 500 feet in thickness and pass conformably (at least to all appearance) * under the Pebble Beds of West Down Hill near Budleigh Salterton.

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* See, however, remarks by the Rev. A. Irving, Quart. Journ. Geol. Soc., vol. xliv., p. 156 ; and A. W. Clayden, Proc. Geol. Assoc., vol. xvi., p. 148.

Fig. 9.—*Section across the Crediton Valley from Newbuildings to Oldridge.*

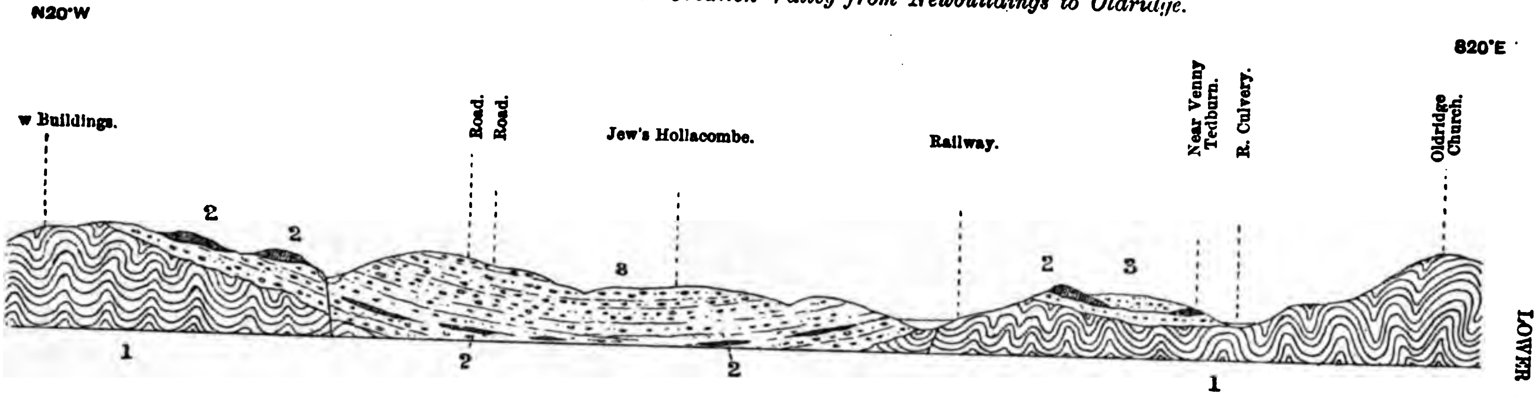
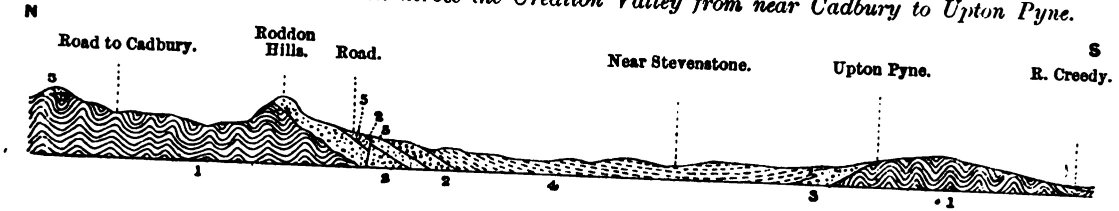


Fig. 10.—*Section across the Crediton Valley from near Cadbury to Upton Pyne.*

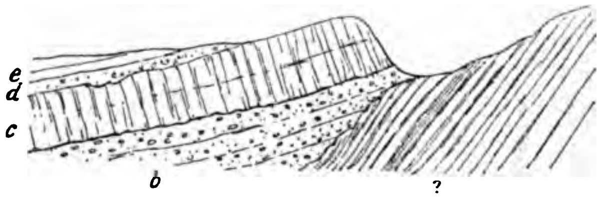


5. Sand-rock.
4. Brecciated sand, loam, and clay.
3. Breccia
2. Igneous rocks.
1. Culm Measures.

It will be seen therefore that this Marl series consists of two members, marls without sandstones upon marls with sandstones, intercalated at irregular intervals. As the upper beds of the underlying series consist mainly of sand rock and soft sandstone, the intercalation of sandstones in the marls between Straight Point and Exmouth might seem somewhat suggestive of a passage series*; but if this were the case we should expect to find an increasing downward development of sandstone in the marls which is not proved by the coast section. It has also been found impossible to trace any boundary from Straight Point northward which could be taken as a separation between an upper series without, and a lower with sandstones, and probably owing in part to faults, no continuous sandstone horizon can be traced from the coast inland.

From the southern margin of Sheet 325 the Marl series extends northward in unbroken continuity throughout the eastern part of the map, over a considerable tract of more or less undulating ground which rises westward, attaining its greatest elevations on the slopes of the Pebble Bed feature, and where Pebble Beds have been denuded from the summit. In the valleys of the tributaries of the Clyst the flat ground has been mapped as alluvium, as the Marls seem to have been re-deposited on an extensive scale. The presence of sandstones in the series, which will presently be more particularly referred to, has been shown on the map where possible. It will be seen that there are no indications of sandstone in the Marls north of Whimple, and that south of that place their occurrence is very local, such as might be explained by natural impersistence complicated by faults.

FIG. 11.—*Diagram to show the unconformability and overlap of the New Red Sandstone (Permian rocks) in the Crediton Valley.* (Sir A. GEIKIE.)†



a	Culm-measures.
b	Breccias and sandstones.
c	Lava-group.
d	Breccias with fragments of lava.

Throughout the Marl area the surface evidence from weathering, gravelly washes and soils, and from the absence of good sections, is somewhat obscure, but, except in the low tract on the south and east of the inlying Culm Measures of the Clyst St. Lawrence district, this obscurity is not sufficient to mask the occurrence of sandstones, where present in any recognisable quantity, although it prevents the discovery and tracing of faults. Faults in the Marls, judging from the coast section and their faulted relations to the Pebble Beds and overlying sandstones between Woodbury Common and West Hill Church (on the E. margin of the map) are no doubt numerous.

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* An intercalated series of sands and marls forms the base of the Marl in the area between Wellington and Wiveliscombe, where it can be traced for some miles.

† Ancient Volcanoes of Great Britain, vol. ii., fig. 229, p. 97, 1897.

From Exton northward to Loxbrook Farm (East of Broad Clyst), the boundary of the Marls with the sands of the underlying series seems to be almost unaffected by faults, and as shown on the map to behave in the manner of a conformable natural junction. In tracing this boundary there were few discoverable indications of intercalated sandstones in the lower part of the Marls, and in one place only was an outlier of Marl on the sands found—near Clyst St. Mary. From near Loxbrook Farm a broken boundary line has been drawn enclosing a belt of low-lying land flanking the inlying Culm Measures, from thence to Langford. This belt of land may include the basement beds of the Marls, and the upper beds of the underlying series, as within it there was not sufficient evidence to determine the exact nature of the rocks, which may consist of marl, loam, and sand. A similar difficulty was encountered near the Culm rocks at Ash Thomas and Moorstone, N. of Collumpton.

The relation of the Marls to the overlying Pebble Beds, though often complicated by fault, is everywhere that of a natural conformable junction. On the slopes and surface of the Pebble Bed feature, the Marls are often concealed by pebbly soil washes, as shown on the west and north of Woodbury Common, on Aylesbeare Common, and west and north of Rockbeare Hill.

The soil of the Marls has been largely used for brickmaking, pits for that purpose have been opened in the upper and lower parts of the series. Clay pits exposed during the survey of the district were noticed in the following localities:—

In a brickyard near Bagmores Farm (not on the old 1 inch map); on the slope of Woodbury Common, near Cannonwalls Farm; near the smaller sandstone patch, north of Woodbury Salterton.

Between the fourth and fifth milestones on the Roman road, twelve chains from the houses then known as the Cat and Fiddle Inn, in a brickyard; by the same road, east of Whitecross and by the turning from Whitecross to Greendale Barton, in brickyards; between the Pebble Bed patches on the south of Aylesbeare Common, and near the house (Woolcomb on the old 1 inch) on the margin of the larger patch; between Denbow Farm and Farringdon House; between Farringdon and Parkyns Village; at a few chains west of Rill Farm; at thirty chains north of Aylesbeare Church; on the margin of the Pebble Beds south of Little Houndbeare Farm; at about a mile and a mile and a quarter east from Clyst Honiton Church; in the valley between Straightgate Farm and Rockbeare Hill; in a brickyard between Strete Raleigh House and Rockbeare Hill; at twelve chains east of Rockbeare Church and in a brickyard by the high road about a quarter of a mile north-east from the Church; between Rockbeare and Clyst Honiton, north of Treasbeare Farm; in two or three places south-east of Whimple; north of Talaton; in a brickyard east of Clyst Hydon.

In these exposures and in road cuttings or banks, the cuboidal structure so marked on the coast is seldom apparent, a thick clay soil, sometimes strong and clunchy, sometimes loamy or gravelly, from admixture with the sand and pebbles washed down from the Pebble bed feature, or from relics of redeposits left in the denudation and eastward recession of the Pebble bed escarpment, forms the surface. The Cat and Fiddle brick pits exposed red loamy clay on red clay, with greenish mottling.

Dark red clay splitting in nearly vertical irregular cracks, and occasionally mottled with grey, was shown in the brick pits east of White Cross.

The brick pits near Rockbeare Hill showed red slightly plastic clay, for 5 feet from the surface, upon Marls. In the smaller pit red loamy clay was exposed to a depth of about 6 feet. The Marl after being exposed to weathering and sundried was used for brickmaking without addition of sand, whilst the overlying clay when mixed with sand was employed in the manufacture of tiles.

In the brick pit, east of Clyst Hydon, red grey-mottled loamy clay was excavated.

At the bridge over the railway at Southbrook Farm, north of Rockbeare there was an exposure of red, finely divided, Marl splitting along irregular horizontal laminæ, and mottled with greenish streaks and spots.

Sandstones occur in the Marl area at Exton; at the Mill between Exton and Woodbury; between Woodbury, Rydon Farm and Pilehays Farm, with two marl outliers; at Lower Bagmores Dairy, south west of Postlake Farm, capped by marl; on the west of Woodbury Salterton; in two patches between Greendale Barton, Windmill Hill and Whitecross, the smallest of which forms a marl-capped knoll; in the valley at Parkyns Village; in two places between Upcott and Allercombe where beds of rock sand are exposed by the lane on the hill; at Strete Farm on either side of the alluvium, and at Cobden bounded by alluvium on the south. Besides these there are tiny patches of sandstone at Rill Farm, near Aylesbeare, and on the east of Farringdon Church. At Greendale, south of Creedy Barton, a band of sandstone occurs in the Marl, and also traces of sandstone, which are probably lenticular, and are all too insignificant to show on the map.

On the north of Marlborough Farm there appears to be an intercalation of clay and sand at the base of the Marls. A bed of sandstone also occurs near Southbrook Farm north of Rockbeare, and in two places below the gravel patch east of Broad Clyst, apparently near the base of the Marls at Loxbrook and east of Southern Lake. Bearing in mind the amount of weathering and superficial reassortment to which these Marl districts have been subjected, it is by no means improbable that sandy intercalations occur in the lower beds, and have almost entirely escaped detection.

The belt of doubtful ground bounding the Culm Measures of Clyst St. Lawrence and Clyst Hydon often presents loamy and sandy soils, and bearing in mind the brecciated clays of the underlying series at Exeter, it is not improbable that clays should locally replace the upper beds of that series on the flanks of an inlier of Culm shales and grits. The road from Woodbury to Rydon Farm exposed red sand-rock in places much false-bedded. The Woodbury sandstones are faulted against Marls on the east, and are probably cut off by a fault under the alluvium of the Exton valley. The correlation of the Woodbury sandstones with those of the Exton Mill, Lower Bagmores Dairy, near Postlake, north of Greendale Barton, Parkyns village, Strete Farm, and Cobden is probable, at least in a general way. It is not improbable that the series of faults which have been traced from the coast section extend to Woodbury and thence to Whimple, cutting out a sandstone horizon only indicated by outlying patches here and there on the west side of a main dislocation. In other words, it is not improbable that the Straight Point sandstones form a series at about 100 feet or so from the base of the Marls, which extends as far north as Whimple, but is only visible here and there by reason of faults and denudation. On the other hand, supposing these sandstone patches to pass under the Marls, their occurrence would be accounted for by faults and undulations bringing up inliers of the subjacent series.

Pebble Beds.

The occurrence of these beds is confined to the western border of the area. Through denudation and numerous faults the superficial extension of this, the thinnest member of the New Red system, is more or less broken and intermittent, although it is less so than the colours on the map might lead one to suppose, as the Pebble Bed patches between the latitudes of Clyst Hydon, on the north, and Whimple, on the south, are almost wholly included in the adjacent Sheet 326. Although in a general way the Pebble Beds have been separated from the overlying Sandstones without much difficulty, and this separation has more or less stratigraphical significance, it is unsafe to regard it as an absolute horizon, since the pebbles which distinguish the former are irregularly distributed in a sand matrix, which in their absence might not be separable from the latter. In places it has been found that Pebble Bed sand was rounded in grain, whilst the grains of the overlying Sandstones were more or less angular, but the observation of the distinction made more than twenty-two years ago was too local to permit of anything like universal application. The sand patches shown on the map on Woodbury Common and further north, near the Warren, may be in the Pebble Beds, and of no stratigraphical value. It was, however, these sand patches which led to the indication of two outliers of Greensand on the old geological map.

In the relations of the Pebble Beds to the underlying Marls no evidences of unconformability have been noticed, although in the following detailed notes very occasional appearances suggestive of a passage or of contemporaneous erosion are described. (See p. 42.) The notes are given *seriatim* from north to south:—

The small Pebble Bed outlier near Woodbeer, in the north-east corner of the area, was not exposed in section, it forms a low-hill feature on which pebbles of grit and quartz occur in red-brown sand soil.

The larger outlier, east of Plymtree, afforded a section in a pit at the bend in the lane on the west of Clyst William farm, showing quartz and grit pebbles in loose red sand. Impersistent strips of sand without pebbles are the only indications of

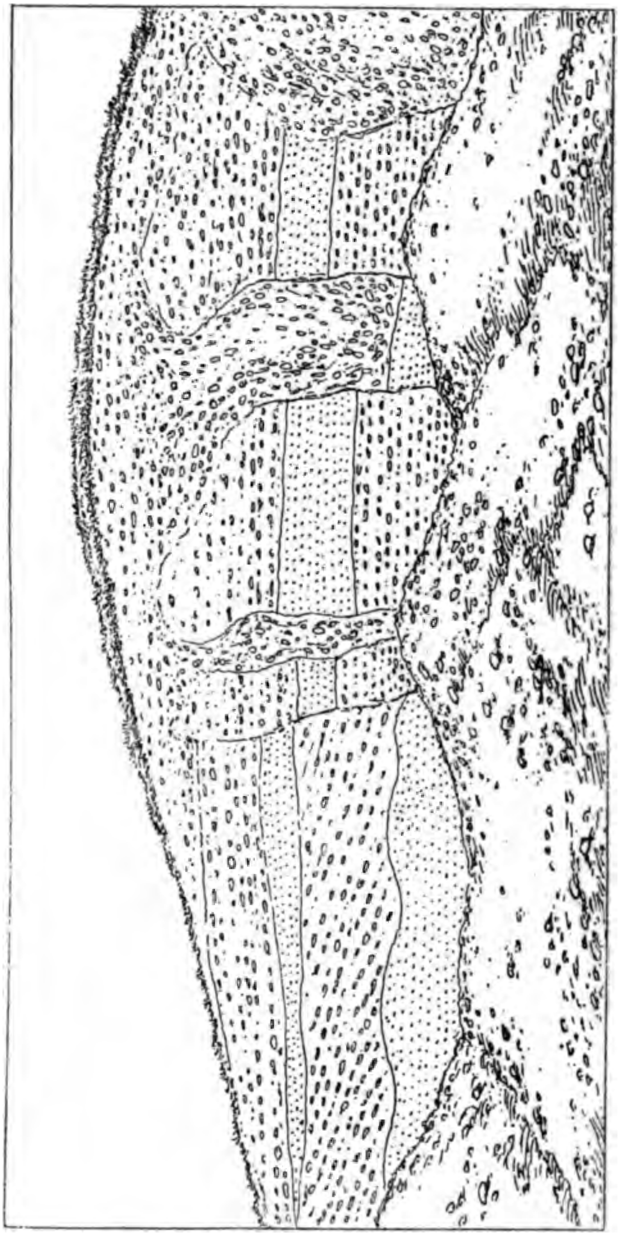

FIG 12. - Section near Larkbeare Court, east of Whimple.

bedding. This outlier may be bounded by a N.N.W. and S.S.E. fault on the south-west side, which, prolonged, would also determine the western boundary of the Pebble Beds on the east of Higher Tale. The Pebble Beds near Larkbeare Court were well exposed in a pit at Larkbeare, on the margin of the map, consisting, as shown in Fig. 12, of gravel and sand. In the gravel are pebbles of quartzite of various sizes, and quartz and grit mostly small, together with a few decomposed fragments, probably of igneous rocks, in a whitish and brownish sand matrix, occasionally exhibiting false-bedding. Bedding is shown by intercalation of light buff sand with occasional pebbles. The section is evidently broken by small faults, but it appears also to have been disturbed by the intrusion of roots, giving the pebbles a vertical tilt, and carrying down the pebbly soil or Head which overlies the whole. The pebbly soil may be due to surface disintegration, if not, it represents an old fluviatile gravel resulting from the waste of the Pebble Beds during a very early stage in the elaboration of the present drainage system in the vicinity.

The wash of pebble débris often obscures the actual boundaries of the Pebble Beds; cases of this kind are to be seen on the map, south of Larkbeare Court, where the gravelly deposit shown at the map margin may be surface disintegration of Pebble Beds *in situ*, or an old gravel resulting from fluviatile waste and redistribution. The Pebble Beds south of Larkbeare Court may therefore have a much greater easterly extension than is denoted by the colouring on the map.

At the cross-roads half a mile north-west from Straightgate Farm, named on the old Ordnance "Straightway Head" the lower part of the Pebble Beds was exposed, as the underlying Marls had been proved at 2 feet below the bottom of the pit. The gravel consists of quartzite, reddish grit, hard dark grey rock, and quartz, in pebbles of various sizes. The increasing prevalence of quartzite pebbles in the Pebble Beds southward from Talaton is worthy of notice. The workmen stated that they had encountered a seam of clay 6 inches thick in excavating the gravel. An exposure near the pit exhibited a bed of grey sand dovetailing into red and grey sand with pebbles and a seam and pellets of red clay. In this case, and at Blue Anchor Inn in the adjacent map, the occasional occurrence of clay in the lower part of the Pebble Beds is worthy of note as suggestive of contemporaneous erosion. At Sampford Brett, in West Somerset, the conglomerates (a prolongation of, and contemporaneous with, the Pebble Beds) are overlain by sandstones intercalated with beds of marl. The exposure at Straightway Head, in descending order, is as follows:—

5. Pebble Gravel (? superficial).
4. White sand, with rolled fragments of red clay.
3. Seam of dark red clay or marl.
2. Whitish sand.
1. Pebbles in whitish sand.

North of Straightway Head, at the turning to Whimple, the Pebble Beds were exposed to a depth of 25 feet in a pit furnish-ing an interesting section. The upper part for from 3 to 5 feet from the surface is probably a redeposit.* The pebbles in it are bound in a coarse greyish and yellowish sandy matrix, and seams of red clay and sand were noticed near the surface in the eastern side of the pit. This gravel rests irregularly on:—

3. Greyish white sand with numerous pebbles, and seams and lenticles of whitish and greenish sand.
2. Red and buff sand, with a few pebbles.
1. Yellowish and whitish sand, with pan (black ironstone) containing pebbles.

North of the above near their termination the Pebble Beds were exposed, and consist of pebbles of grit, quartz and quartzite in a buff and red sand matrix, with seams of buff sand without pebbles in the upper part of the exposure.

The distinctive Pebble-bed feature may be said to commence at this point, and in spite of faults and of the partial removal of the gravels the feature is maintained continuously, forming high ground, for the most part Common land, from hence to the coast near Budleigh Salterton.

In sinking a well at Straightgate Farm, 70 feet of Pebble Beds are said to have been penetrated. The information was furnished by a cottager, living about a quarter of a mile to the east of the farm, where he stated his well had been sunk through 30 feet of gravel. Mr. Champion stated that the well at his cottage, near the last but by the high road (about a mile and a quarter west of Ottery St. Mary Station), was sunk through gravel, sand, and a layer of clay to a depth of 52 feet. The above localities are either just within or just outside the border of Sheet 325. The Pebble Beds of Rockbeare Hill and Broad Oak were exposed in two pits W.N.W. and S.S.E. from Brick House Farm.

South of Broad Oak numerous faults affect the relations of the Pebble Beds, in places cutting them out, and throwing the overlying Sandstones and underlying Marls together, but the continuity of the Pebble Beds is abundantly evidenced by outliers on Venn Ottery and Aylesbeare Commons. Owing to probability of rainwash and redeposit it is sometimes difficult to fix the boundaries of these outliers; for instance, the outlier between Venn Ottery Common and Manor Farm may extend in a thin deposit for a quarter of a mile further northward near the farm. On the east of the Common the Pebble Beds were exposed by the road to Tipton, in one of these pits numerous large ellipsoidal quartzite pebbles occur. The small patch on the south was exposed in road cuttings. The most northerly of the small outliers on Aylesbeare Common afforded a pit section shown in the accompanying sketch. (Fig. 13.)

The tiny adjacent outlier is probably faulted. At the Inn at the eighth milestone Pebble Beds were exposed, probably between faults to which the undulating bedding shown in the section may be ascribed. The beds consist of red yellowish and grey sand, pebbles being irregularly distributed in some of them and entirely absent from others. Between these outliers and the mass, which, though disturbed by faults, can be traced continuously to Woodbury Common, gravelly soils for the most part conceal the Marls. The hill formed by this mass of Pebble Beds is called Colyton Hill on the old 1 inch map. The Colyton Hill Pebble Beds are for the most part marked by feature, they

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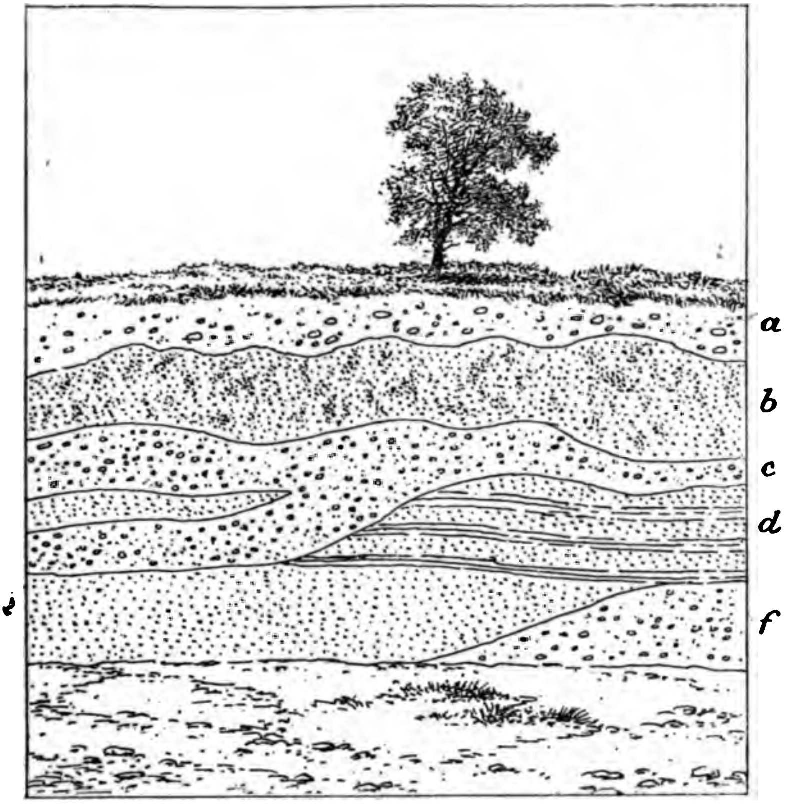
* See De la Beche, Report on Geology of Cornwall, Devon, &c., p. 396.

FIG. 13.—*Section on Aylesbeare Common.*



a Grey sandy soil with pebbles.
b Bright red and grey mottled sand.
c Quartzite quartz and grit pebbles, mostly small, in brownish sand; an impersistent strip of sand occurs in the gravel.
d Red sand with seams of red clay
e Red sand giving place to (*f*) pebble gravel.

were exposed in pits by the high road; in one of these near the ninth milestone the beds consist of red and grey sand; in some beds pebbles of quartzite, quartz and grit are irregularly distributed. Contrary dips suggest a fault, masked by talus, grass and furze. On the opposite side of the road, a section 10 feet in height disclosed:—

Gravelly topsoil with small pebbles	for from 1 to 3 feet.
Reddish brown sand	for from 2 to 3 feet.
Gravel of quartzite, quartz, and grit pebbles of various sizes in sand	4 feet.
Bed of sand	3 feet.
Bed of sand with small pebbles, giving out water at its base	
Band of red clay	
Sand at the base of the exposure	

The general absence of exposures on Woodbury Common enhanced the difficulty of fixing geological boundaries in that heather covered waste; the lines on the map have been adopted after repeated investigation.

The junction between Pebble Beds and overlying Sand on the east of Goosemoor is very indefinite.

The sand patch shown on the map at the Warren was exposed to a depth of 8 feet in a pit. It is fine grained, variegated sand with nodules of ironstone enclosing sand nuclei. On the south side of Woodbury Castle a pit disclosed 8 feet of whitish buff and yellowish sand with thin horizontal red bands. It forms a narrow strip probably bounded by a fault on the south, and possibly terminated by a fault on the west. These sands are probably a part of the Pebble Beds, if not, the latter would have diminished to about half their usual thickness on the north and east sides of the Warren sand patch.

Pebble Beds were exposed in a pit on Black Hill at the southern margin of the map, and again on the eastern edge of Woodbury Common by the stream west of Stowford. The pebbles vary considerably in size, they consist of quartzite, conglomerate with quartz pebbles, quartz and grit, in a matrix of red sand.

UPPER SANDSTONE.

The Triassic sands and sandstones, which form the uppermost Secondary rock, occupy a very small area in the south-eastern part of the district. The sands from the south margin of the map to Stowford seem to rest naturally on the Pebble Beds, as also near Kingston and Stonyford, just north of Goosemoor, in the valley near Higher Matcombe, at the margin of the map, and north and south of West Hill Church; but elsewhere, as on the western side of the outlier on Colaton Raleigh Common, on the north side of Stowford, etc., they are faulted against Pebble Beds on the higher levels and against the Marls underlying them on the slopes or in valleys. East of Tipton Cross a tract of sandstone is apparently bounded on three sides by faults, its junction with Pebble Beds on the north being probably normal To the north of West Hill Church there is no further indication of this division in the map. The fine coast section from Sidmouth to Budleigh Salterton shows the true character of these sandstones. In the small tract included in Sheet 325, exposures are naturally few, and the upper parts of the series are unrepresented. On the old one-inch map the houses near the outcrop of the Pebble Bed, near the margin of the map, are named "Eaton Town." At about 10 chains west of these houses there appears to be a natural junction, although obscured by overgrowth at the crucial point. The exposure was from 3 to 4 feet deep in descending order, as follows:—

Red sand rock intersected by nearly vertical seams of Ironstone (pan).
Rather coarse red sand with darker bands.
Similar sand with seams of small pebbles.

By the turning to Hays Mill near the north border of Sheet 339 (the adjacent map on the south) buff false-bedded rock-sand containing pockets of red loamy clay, was observed. On the hill south of Blackberry Farm, an exposure of reddish brown rock-sand was noted.

By Bakers Brake, north-east of Stowford, red sands and grey and buff sands with red streaks were exposed. False-bedded red rock-sand was observed between Stowford and Kingston.

By the lane on the north of Kingston an exposure of buff and red rock-sand, with occasional flat pieces of black ironstone (pan), exhibited false-bedding in places, and also a slight tendency to a brecciated character. The large sand outlier south of Hawkerland and west of Kingston, is cut off by a fault against Pebble Beds on the west. This fault seems to die out southward, but its N.N.E. prolongation is evidenced near the ninth milestone west of Goosemoor, whence it runs to Benchims. In the intervening valley it cuts off the Sandstone series and underlying Pebble Beds against Marls. At Benchims the fault assumes a northerly direction and near Higher Matcombe deflects toward Brick House, coalescing with two other dislocations, one of which bounds the Sandstone tract of Heathlands on the south.

The large sand outlier was for the most part concealed by a redistributed pebble bed soil and by heather growth, exposures being confined to sand pits near its northerly extremity (S. of Hawkerland). The exposures showed about 4 feet of red sand with seams of black ironstone (pan) upon whitish, buff and pale yellowish sand with reddish horizontal streaks.

Near Stonyford, at about half a mile east of Hawkerland on the north side of the valley, yellowish, buff and red rock-sand containing a band of dark red loamy clay was exposed. This sand may represent the upper part of the Pebble Beds or the base of the overlying series. Between Goosemoor and the outskirts of the common, called Colyton Hill on the old map, the boundary of the sands is most indefinite. In one place the road section showed rather coarse sand-rock under pebbles—if the latter are not redistributed by fluviatile action or rainwash the Pebble Bed boundary would follow the streams round Goosemoor, and the sand series would not be represented west and north-west of that place. These difficulties tend to show the intimate connection of the Sand series with the underlying Pebble Beds, if they do not prove the latter to be the gravelly base of the former.

South of Broad Oak the sands on the map margin seem to contain much black ironstone (pan), to judge by surface fragments.

At Brickhouse Farm the sands appear to pass down into Pebble Beds, as a section by the road exhibited red laminated sand with occasional thin grey seams, under from 5 to 8 feet of red sand with grey streaks containing a few pebbles and sub-angular fragments in lines here and there through it. This upper bed, however, may possibly be a redeposit.

At the map margin near West Hill Church red sand was exposed in a well under a gravel soil, probably redistributed Pebble Beds from 6 to

7 feet in thickness; water was obtained at 35 feet from the surface. The well appears to have been sunk to some depth in the Pebble Beds and through the base of the overlying Sand series, as Pebble Beds were exposed in a pit at 2 or 3 chains to the north of it, consisting of pebbles chiefly quartzite and quartz in red sand which occurs also in two lenticular seams in the gravel.

In the above notes no mention of the occurrence of calcareous matter in the Sandstone series is recorded, the concretionary character observable on the coast section may however occur at a higher stage in the series than the parts of it embraced in Sheet 325. The partially consolidated character of the rock which is, strictly speaking, rather a sand-rock than a sandstone also favours this view. The occurrence of clay pockets and seams in two of the localities is worthy of note as suggesting a comparison with the intercalated marl and sandstone at the base of the Sandstone series at Sampford Brett, near Williton.

CHAPTER IV.

CONTEMPORANEOUS IGNEOUS ROCKS IN THE LOWER PART OF THE NEW RED SANDSTONE.

1. STRATIGRAPHICAL RELATIONS OF THE EXETER TRAPS.

Conybeare and Phillips* point out the occurrence of masses of amygdaloidal trap interposed between beds of the New Red Sandstone formation at many points along a line of from five miles north to five miles south of Exeter, such as the localities of Killerton, Silverton, Thorverton, at Upton Pyne, Poltimore, and Poucham, a little north-east of Exeter (evidently the West Clyst patches), south-west of Exeter, and near Dunchideock.

A still earlier reference to the amygdaloid of Poucham, Upton Pyne, and Thorverton was made by J. F. Berger in 1811,† while W. G. Maton (as well as Polwhele) noticed the volcanic characters of the Thorverton Stone in 1797.‡

In these references two localities are difficult to identify, viz., Poucham, which might refer to Posbury, although it looks like a corruption of Pocombe; and Upton Pyne. The description of the Upton Pyne occurrence by Conybeare and Phillips, viz., conglomerate of Heavitree type, under several feet of red argillaceous sandstone, resting "on felspar in mass, containing a few laminæ of calcareous spar and some crystals of quartz, forming the roof of a mine of black oxide of manganese which is worked to the open day," is rather descriptive of the Crediton valley breccia, with numerous felspar crystals and quartz porphyry and other igneous rocks than of trap. In De la Beche's Report, 1835,§ a much fuller account is given of the various occurrences of trap, and Mr. W. Vicary in 1865 recorded the discovery of new localities,‖ and the results of excavation in some of the well-known quarries. In the old geological map, as may be seen by a comparison of Sheets 21 and 22 with the Sheet under description, it will be found that the boundaries of the Trappean rocks are generalised as between Exeter and Dunchideock, at Killerton, Dunsmoor, and S.W. of Crediton, whilst the re-survey has proved the severance of parts of these masses by denudation; secondly, that in some cases, as between Beare and Budlake, and in Silverton, the strike of the rocks seems to cross the new boundaries at right angles; and thirdly, that the present map shows patches at Fishford Farm, south of Broad Clyst, south of Spraydown House, on the north-west side of Silverton, and north and west of Thorverton that are not indicated on the old map.

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* Outlines of the Geology of England and Wales, 1822, pp. 294 to 298.
† Trans. Geol. Soc., vol. i., pp. 100–102.
‡ Observations on Western Counties of England, vol. i., p. 96.
§ Report on the Geology of Cornwall, Devon, etc., pp. 199 to 216.
‖ Trans. Devon. Assoc., vol. i., p. 43.

Mr. F. Rutley visited Exeter during the re-survey in 1876, and examined the traps of Knowle, Western Town, and Pocombe (south-west of Exeter), and of Killerton, Rewe, Raddon, and Posbury. He regarded the rocks of Knowle and Western Town as olivine basalts, and considered basalt a term applicable to the series with the exception of Killerton, where he inclined to regard the rock as a Minette.

In 1887, during the re-survey of the older rocks of the Chudleigh district, the Dunchideock basalt was reinvestigated. Dr. F. H. Hatch pronounced the Dunchideock rock and that of the neighbouring mass at Knowle to be porphyrite, the Pocombe, Raddon, Crabtree, and Budlake (east of Killerton) rocks to be Olivine basalt or melaphyre, and the Killerton Park rock a Mica porphyrite. Baron von Reinach visited the Exeter district under the writer's guidance in 1891. He submitted specimens of the traps then collected to Professor Bücking, who pronounced the Dunchideock rock to be melaphyr with Olivine and Bronzite,* the Posbury and Pocombe rocks to be melaphyr with Olivine, and the Knowle and Spencecombe (north-west of Crediton) rocks to be Mesokeratophyr, and Biotitmelaphyr with Olivine.†

In 1892 Mr. Bernard Hobson communicated an important paper on the basalts and andesites of Devonshire to the Geological Society, the result of the examination of a series of specimens collected by him on the spot. All the localities, with three exceptions, are to be found in Sheet 325. They are as follows:—

From three quarries in the Dunchideock mass; from a quarry known as Knowle quarry in the adjacent mass on the north between Darniford and Higher Whiddon; quarry apparently in the larger mass of the Westown patches (Western Town on the old map); large quarry near Pocombe Bridge by the high road to Exeter, known as Pocombe Quarry; quarry north of the above in the Barley House patch; quarry at West Clyst, opposite the turning to Poltimore Park; from four quarries (one being in Columbjohn wood near the western extremity of the mass) in different parts of the most southerly of the two large masses in Killerton Park, and from one quarry in the northern mass; from quarry in the patch between Killerton and Budlake; quarry at Beare Farm; quarry north of Rewe by the road to Silverton near Heazille Barton; quarry at Dunsmoor, the easternmost of the three patches near Stumpy Cross, about 59 chains south of Silverton Church; old quarry (now a pond) in the grounds of Silverton Park (Combe Sachville) 195 yards west of the house; Raddon Quarry in the mass west of Thorverton; Posbury Quarry.

For the more precise localities of the quarries the reader is referred to Mr. Hobson's paper.‡

It will be seen from the notes in preceding chapter on New

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* Rev. J. J. Conybeare (Ann. Phil., Sept., 1821, p. 165), doubtfully mentions "bronzite" as a constituent of the Amygdaloid. Mr. B. Hobson failed to detect it in his specimens of the Dunchideock rock.

† Geol. Mag., No. 336, p. 247, June, 1892.

‡ Quart. Journ. Geol. Soc., vol. xlviii., p. 496.

Red rocks, that making every allowance for the considerable denudation which the Trap rocks have evidently undergone, at least, in the district south of Exeter and in the Crediton area, their distribution points rather to a series of local eruptions, than to a connected stream or streams of lava emitted from one seat of eruption, and subsequently insulated by denudation.

There is also, as may be seen from their situation, a considerable difficulty in the way of regarding such rocks as the basalts of the Exeter and Dunchideock district evidently at or near the base of the New Red rocks, as contemporary with the West Clyst, Wishford Farm and Poltimore patches, although their contemporaneity with the Posbury and Spencecombe masses is not unlikely.

It will be convenient in the following notes to treat the rocks in the order and manner of their occurrence in local chains or clusters as follows:—

1. Dunchideock to Exeter.
2. Poltimore and West Clyst.
3. Killerton.
4. Silverton.
5. Thorverton.
6. Crediton.

I. DUNCHIDEOCK TO EXETER.

Dunchideock.

The Dunchideock basalt commences at a quarter of a mile south of the area in Sheet 325, but near Whiteway, one and a half miles further south, there is some indication of similar rock. The superficial extent of the basalt on the north side of the fault, although doubtless due to a great extent to the denudation of overlying breccia, may be also ascribable to a greater original thickness. A short distance south of the fault a band of New Red strata of local derivation from Culm rocks intervenes between the Culm and basalt, continuing northward round the mass almost as far as Dunchideock. At and east of Dunchideock the basalt rests directly on Culm rocks forming a thin attenuating band separating them from the overlying breccias. It is rather doubtful whether this band is superficially continuous in the valley bottom with the basalt of the Knowle mass south-east of Idestone, but that they were originally connected in mass between Idestone and Dunchideock is exceedingly probable.* In the Idestone lane the basalt is much mingled with masses of hard breccia and indurated sandstone with pale greenish spots, as if caught up in a lava flow. The rock exhibits both the vesicular and non-vesicular type. In the former agates have been formed in some of the vesicles, suggesting some comparison with the German "Mandelstein." Deposition prior to the lava flow is shown by a fringe of breccia resting on the Culm and indurated at contact with the basalt. This intervening stratum extends for some distance on either side of Idestone. The overlying breccia at the cross roads west of Marshall Farm contains fragments of the trap and altered rocks in a red loamy matrix. In one spot nodular fragments of brown scoriaceous-looking rock were noticed. (See Fig. 14.)

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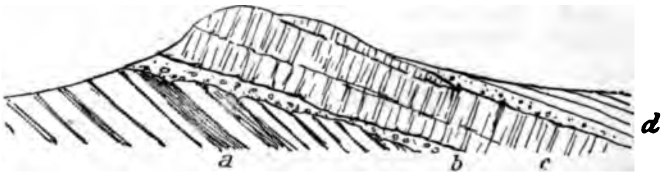
* It should be mentioned that "Knowl" was the name given on the old series map to a farm about a mile N.W. of Idestone. Its position is east of Ramridge on the new series map. The locality must be distinguished from Knowle, by Spencecombe, W.N.W. of Crediton.

De la Beche says:* "Above Ideston and Knole we find porphyries sometimes containing crystals of quartz, at others of felspar, and occasionally of both together—a very interesting fact, inasmuch as it is the only locality with which we are acquainted where any portion of those quartziferous porphyries, of which fragments are so commonly found in the red conglomerate between Exeter and Teignmouth, occur in place." "I hold," says Mr. Hobson, "that De la Beche was misled by the quartz inclusions in these basalts into regarding them as quartz porphyries." De la Beche also refers to the intimate connection of the traps of Western Town with the "conglomerates and sandstones above them," and to their apparent intermingling near Ideston.

FIG. 14.—*Section at Belvidere, near Dunchideock.* (Sir A. GEIKIE.)†



b Breccia (with Culm Measure stones), sand, and loam.

a Culm-measures.

d Red breccia, with fragments of igneous rocks and boulders of quartz porphyry.

c Lavas.

By the road to Haldon Belvidere, a quarry shows very hard dark bluish grey basalt, with veins or fissures at various inclinations containing red sandy material, and lined with chalcedony and carbonate of lime.

In the lower part of the Dunchideock basalt by the road to Doddiscombsleigh, at Dunchideock Church and in other places, overlying sands have filled cooling cracks in the basalt by downward filtration. Mr. Vicary mentions the occurrence of lithomarge in the trap at Haldon.

Westown.

The Westown basalt forms a group of five patches, three of which are small, and apparently bounded by fault on the north, and one near Halscombe surrounded by breccia, at some distance from the others. The largest mass appears to rest on Culm Measures on its northern margin, but to have overlapped the edge of prior New Red deposits, as Mr. Vicary* had a pit dug in the quarry floor and found a layer of indurated sandstone,

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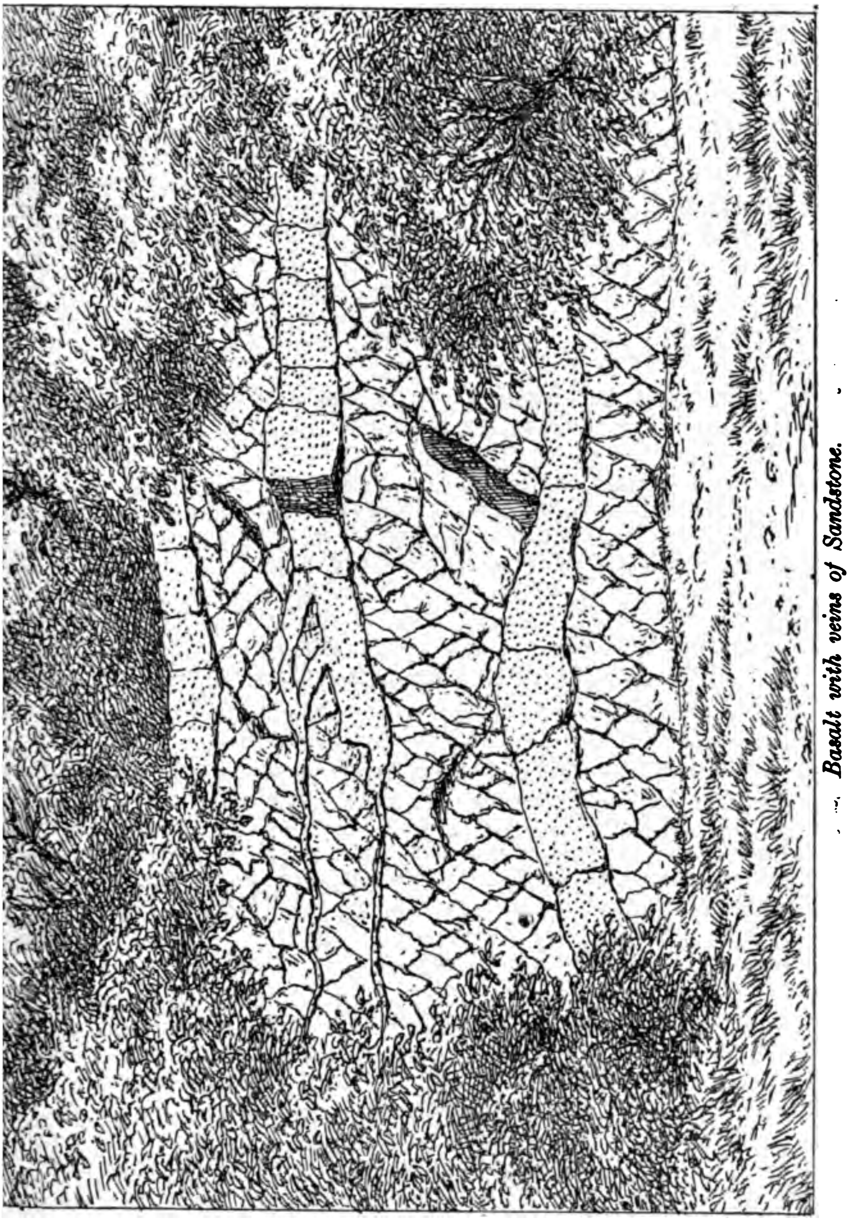
* Report on the Geology, etc., p. 203.

† Ancient Volcanoes of Great Britain, vol. ii., fig. 228, p. 97, 1897.

FIG. 15.—*Section at Westown, Ide.*


Basalt with veins of Sandstone.

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[*] Trans. Devon Assoc. for 1865, p. 49.

ordinary loose conglomerate containing trap pebbles and Beekites. Unless the trap pebbles mentioned were scoriæ or other volcanic ejectamenta preceding the outflow of the Westown lava, their presence in the breccia beneath basalt would point to the existence of earlier emissions concealed by the New Red Rocks, and would tend to impair the value of the basalts as a relative stratigraphical horizon.

The sketch (Fig. 15) shows the association of hard light red sandstone, mottled with grey spots, in decomposed basalt in a disused quarry in an orchard at Westown. It is difficult to account for the interlacing of the sediment, unless we suppose lava flows with intermediate sandy accumulations successively disturbed, sheared out, and baked. The small patch on N. of Westown appears to be surrounded by Culm rocks, and probably owes its position to a fault.

Pocombe.

The original connection of the Pocombe and Barley House trap patches is sufficiently obvious, but there is no proof of their having formed a part of the Western Town and Knowle rocks. De la Beche alludes to the "Pocombe rock" as "chiefly a hard siliceo-felspathic compound with occasional, though not numerous, vesicles . . . much employed for roads and buildings. The vesicular character is more apparent . . . on the north at Little Barley than at the great quarry near the high road." Mr. Vicary gives the thickness of the Pocombe basalt as from 30 to upward of 70 feet. A pit in the deepest part of the quarry floor, filled up prior to 1876, penetrated Culm shales.

The road cutting opposite to the quarry entrance showed very hard dark bluish grey basalt on horizontal beds of hard fawn-coloured sandstone, inosculating with basalt and resting on Culm shales and grits, which break in small pieces and betray slight indication of alteration near contact. The actual junction of the basalt with the overlying sands, loam and breccia with igneous fragments was not exposed, but the latter were seen very near it, and afford easterly and south-easterly dips by the lane to Ide. A thin gravelly layer apparently impersistent separates the basalt from the Culm in places.

The Barley House basalt patch was imperfectly exposed in more or less overgrown quarries in which the rock contains small red (decomposed) mica flakes and occasional crystals of sanidine, and locally seemed to inosculate with hard red sandstone.

The northern part of the Pocombe mass was exposed in a lane, the section resembled that in the quarry in the West Clyst patches opposite the road to Poltimore. Tough blackish sandstone and red and brown sand with fragments of basalt occur in an irregular dyke-like manner in vesicular basalt (pisolitic vesicles filled with a white substance) much disintegrated in places. Mr. Teall regards the Pocombe rock as a trachyte with olivine.

Northernhay, Exeter.

Mr. Thomas Andrew remarks on the Northernhay rock as follows:—"If a line be drawn from Gandy Street up the High Street to Longbrook Street, then descend to the bottom of the street and follow the line of the ancient brook to the South Western Railway Station, you will find encircled the igneous rock on which the Castle of Exeter stands. The least exposed portion of this rock is very compact and ponderous. It numerous fissures crossing it in all directions are filled with white hard veins of calcareous spar. Above this the stone is more porous and light and without veins. Its ground inclining to red is charged with numerous very small specks of white calcareous spar. Near the surface it is still more porous, light and ruddy, and the many white spots now enlarged and filled with a white soft chalky substance give it some resemblance to the Derbyshire toadstone. When the cells are emptied of their contents (by weathering) the stone has much the appearance of the pumice; but it still retains considerable weight. It at last degenerates into a red clay, which comprises the surface of the Castle Hill, from whence no doubt this eminence received the name of 'Rougemont.'" [*]

This is the best macroscopic general description of the Trap of the Northernhay type to be met with, and is given here as the exposures are now very insignificant. Mr. Andrew informs me that an excavation in Southernhay recently (1900) exposed trap, either a tongue from the Northernhay mass or intrusive in the New Red.

The Northernhay rock is now very imperfectly exposed in the Northernhay pleasure ground. De la Beche[†] tells us that, at two or three years before the date of his Report, 1835, a good section of the rock was exposed "when a new road to Tiverton was cut through part of its base: much vesicular rock was seen, the vesicles often containing a green earthy mineral readily removed by atmospheric influences." He adds, that judging from the stones in the old walls of Rougemont Castle, "a large proportion of which were probably taken from the spot on which it is built, vesicular rocks must have been commonly quarried at that period on Rougemont, some of this rock being porphyritic from the dissemination of crystals of felspar through the mass."

Dr. Shapter[‡] alludes to the trap boundary as passing "along Southernhay to the middle of the Cathedral yard," and crossing Fore Street and St. Paul's Street, but no proof of the extension of the trap across the High Street was obtained. In junction with the Culm Measures the Trap extends from Hills Court Nursery, along the north side of the South Western Railway, from Barrack Lane to the New North Road railway bridge, and thence along the base of the steep slope in Northernhay grounds to Queen Street. Excavations in the cutting between New North Road and Barrack Lane bridges in 1877 disclosed very vesicular trap at the Weighbridge near the former, whilst, near the latter, trap with vesicles full of a white substance was exposed. At 2 chains from Barrack Lane bridge bluish Culm shales, reddish grit and red clay were visible, probably along an oblique fault leading south-east, so as to allow of the northern side of the cutting being faced with Trap. At a walled-up portion very hard trap seems to have been got out in large blocks of a lilac-brown colour, with small iron shot vesicles, recalling the Barley House rock.

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[*] From a paper printed for private circulation, entitled "The Geological Phenomena of Exeter and its Neighbourhood."

[†] Report on Geol., etc., pp. 203, etc.

[‡] The Climate of the South of Devon, 2nd edition, 1862, p. 67.

In an excavation for sewage (March 27, 1900) where Northernhay Place joins the High Street, the Northernhay Trap was encountered under 3 or 4 feet of made soil, was visible for some feet, and was said to have been encountered down to 18 feet from the surface.

The Trap may occur in a thin impersistent sheet under old river gravel between the Higher Market and Queen Street Station, extending for a short distance down Paul Street and Northernhay Street.

In drainage excavations in front of the chambers between the G. P. O.* and Albert Memorial Museum in Queen Street, Culm shales were reached at from 5 to 6 feet from the surface, under surface earth, gravel, and marl. Unless the term marl was applied to a thin layer of decomposed trap it must be included in superficial deposits.

In the foundations of the Rougemont Hotel Trap was exposed under a very uneven capping of gravel and clay, averaging 6 feet in thickness.

On the east side of Northernhay drainage excavations disclosed the following section near Edwards' Hat and Cap Factory in 1876:—

	Feet.
Made soil	3
Reddish brown earthy clay with stones	4
Grey clayey band	1
Decomposed trap visible to a depth of	7

In 1876 the foundations of a house in Musgrave Alley near the (then) residence of Mr. J. M. Martin, C.E., disclosed very rubbly decomposed Trap; the sides of the excavation seemed to be in made ground, or disturbed materials of New Red breccia.

The relations of the Northernhay Trap to the New Red rocks are by no means clear.

II. POLTIMORE AND WEST CLYST.

The Poltimore Trap patches are five in number, one on either side of the Culm inlier north-east of Pinhoe, one in contact with the spur of Culm Measures at Bampford Lodge, near Poltimore, and two near Wishford Farm, south of Broad Clyst. The occurrence of basalt at Wishford (Fishford on the old map) Farm was first pointed out in 1865 by Mr. Vicary.

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* Since removed to the High Street.

The Culm inlier forms a hill feature; along its southern boundary at West Clyst Farm Trap is evidenced for half a mile, its relation to the New Red Sands on the south was not visible. On the north side of the inlier Trap is exposed in a quarry opposite the Gatehouse to Poltimore Park. The rock consists of hard grey basalt splitting into small pieces; it is in part vesicular, in places intersected by uneven joints resembling a rude cleavage, and at first sight simulating the appearance of an altered sedimentary rock. The quarry faces are intersected by four vertical dyke-like masses of tough red sandstone, mottled with small greenish spots, partly blackened by manganese, and frequently exhibiting a nodular jointing. The pipes of sandstone in the Trap would justify the inference that the surrounding New Red sands were deposited upon it. The Trap is locally called "Malm."

Between the western end of the inlier and the Culm boundary near it westward there may be a small patch of Trap, but the evidence was deemed too obscure to warrant its indication on the map.

The Trap of Bampford Lodge, Poltimore, was very imperfectly exposed, the rock appeared to be much decomposed, and contains large vesicles filled with a white substance. Its relations to the Culm on the north-west and to the New Red sands were not visible, it may be faulted against the former and pass under the latter.

The two patches of Trap, at and east of Wishford Farm may be connected, and bounded on the north by a fault possibly bringing up a strip of Culm Measures, of this, however, no sufficient proof could be obtained. At Wishford Farm red and brownish laminated sandstone furnished a southerly dip of 13°. Just north of the farm Trap was exposed, its junction with the sandstone being concealed. On the west side of the road very vesicular Trap was quarried, the vesicles being filled with white substance. The rock is partly disintegrated, and toward the surface forms a rubble of angular stones. In one part ironstone nodules, binding nuclei of red sand, appear to be residual from the denudation of overlying sands. A quarry in fissile sandstones north of the above gives southerly dips of from 20° to 35°, and in one part as high as 43°. Unless the sandstones are false-bedded on a very large scale, these dips point to a fault boundary, probably on the north side of the Trap.

The easternmost Trap patch was evidenced by surface stones, and in a small disused quarry near the lane. An imperfect section in the lane, 5 feet in height, showed a boss of Trap between laminated blackish sand-rock and reddish and blackish laminated sandstone, the laminæ being converted into ironstone, and curved or bent over near the Trap rock.

The position of the Wishford Farm Traps unless an extensive fault intervenes between them and the outcrop of the Marl series on the east, either places them some hundreds of feet higher in the New Red rocks than those of the Dunchideock series, or necessitates an unconformity between the sands and overlying marls. The same argument applies to the Traps of the Killerton district.

III. KILLERTON.

The Traps of the Killerton district consist of seven patches and a few very small exposures, generally faulted repetitions of the base of the neighbouring patches. The group is continued between the Exe and Culm rivers, by eight or nine masses between Rewe and Silverton.*

The andesite of Killerton Park forms a hill feature breached by a valley which seems to have been cut through the Trap to underlying New Red beds thus separating it into two large masses. The southern mass extends from the high road at the sixth milestone over Dolbury Camp to the western end of the wood near Columbjohn. The rock breaks through the copse crowned summit in very hard dark grey crags, and is also exposed in small quarries and in quarries in the wood near its western extremity, but its relation to the New Red sand and loam was everywhere hidden by the grassy slopes.

On June 24, 1876, an excavation behind Killerton House showed brown loamy soil with numerous rather large fragments of the igneous rock upon red sand-rock with grey bands, and impersistent marly seams. In the disused quarries near its western extremity the igneous rock was only partially exposed. In one quarry a breccia or volcanic agglomerate was exposed consisting of light red indurated sandstone with buff spots associated with numerous fragments of vesicular trap. In an adjoining quarry a thick bed identical in character with the above rests upon trap vesicular throughout, and passing or giving place downward to a compact rock which forms the lowest part of the exposure.

At Columbjohn an old river terrace deposit conceals the rocks, but on September 27th, 1876, an excavation on the north side of Columbjohn Mill (named on the old map: the most northerly houses by the alluvium on the new), to a depth of 6 feet, disclosed disintegrated trap, and near it red loam of the New Red, but the junction was concealed by talus. It is not certain whether the Trap is a small faulted patch, or a westerly continuation of the mass on the east.

The northern mass in Killerton Park, although extending over a considerable tract of elevated ground, is, with the exception of small quarries near its eastern margin, indicated by surface stones and partial superficial exposures, but these were sufficient to leave no doubt as to its boundary on the north and west. Between Killerton Park and Budlake the relations of the patch of Trap are very indefinite; as far as surface evidence enabled one to judge the New Red surrounding it might rest irregularly upon the Trap, but if this is the case the patch must be bounded by a fault on the south, as the deep lane cutting to Budlake in immediate vicinity to a quarry in the Trap, seems to have been entirely excavated in the New Red. The relations of the Trap are, however, not sufficiently clear to prove whether the igneous rock might be part of a lava flow or a neck or pipe. As exposed in the quarry the rock is for the most part compact and of a light colour, but it exhibits a darker colour and highly vesicular character in places. No distinct alternation between the compact and vesicular varieties is observable, although a structure resembling bedding is apparent throughout. In one place a vein of whitish arenaceous matter, about 6 inches thick, vertically intersects the igneous rock, which exhibits a vesicular character at contact with it. Mr. Rutley considered the rock to be "in external appearance much like a dolerite occurring near Glasgow but differing from it under the microscope in having less distinct crystals developed, and in the more plentiful occurrence of amygdaloidal cavities. It is more or less rich in iron oxides and in carbonates, probably of lime."

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* See also Sir A. Geikie, Ancient Volcanoes of Great Britain, vol. ii., p. 98.

By the high road between this patch and Killerton (south of Crabtree on the old map) a small patch of igneous rock, like a minette, rests irregularly upon rubbly gravel* on red clay and sand—near this a good-sized block of similar rock was observed in the New Red. The absence of appreciable alteration at contact in the gravels suggests the idea that the igneous rock at the top of the section, as well as the smaller piece, is a block derived from the Killerton mass, but if so, the Killerton rocks would be older than the surrounding New Red, and might, as far as surface evidence goes, be intrusive.

The lane from Budlake eastward toward Hollis Head furnished an interesting section of Trap patches, remnants of a formerly continuous lava resting on New Red rocks and stepped by nearly north and south faults. Proceeding westward from the New Red gravels a patch of Trap is exposed resting upon blackish sand succeeded by gravelly beds upon red clayey and loamy materials. The Trap junction is repeated by two faults 34 yards apart. Red sand was exposed near Budlake, but much of the section was walled up. These faulted patches cannot be traced, and seem to terminate on either side of the lane along their respective faults. In the northern avenue to Sprydoncote, however, there is evidence of Trap probably along the continuation of one of the faults. A patch of Trap may occur at Sprydoncote, but no sufficient evidence of it was forthcoming.

On the south of Sprydoncote Trap makes a hill feature on which evidence of its occurrence is afforded by surface fragments and small excavations in which the rock is much decomposed; altered sandstones crop out near the base of the hill, apparently passing under the Trap at its south-western margin. Between Beare and Lower Comberay Farms there are two patches of Trap separated by a tongue of New Red, but in close proximity at their northern extremities. A quarry near the northern end of the easternmost patch at Beare Farm gave the following section:—

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* This may be the locality mentioned by Conybeare and Phillips where they observed the igneous rock "resting on the large grained conglomerate" on the road from Killerton to Silverton, Geol. Eng. and Wales, 1822, p. 298. The fact was also noticed by Mr. Vicary.

	Feet.
Brown sandy surface soil.	
Red loam and sand with fragments of Culm grit - - - -	5
Soft red rock-sand - - - - - - - - - - -	5
Dark red rock-sand with greenish grey spots containing fragments of Trap in the lower part - - - - - -	5
Finely vesicular Trap forming the lower part of the quarry.	

At the entrance to the quarry the Trap seems to be cut off by a fault throwing down New Red rock on the west and probably running into the fault at Beare. Taking the relations of the Poltimore and Killerton Traps in review we have positive evidence of New Red rock overlying them at Beare and probably also in the Budlake patch, south of Sprydoncote, as well as in the Wishford Farm and Poltimore patches, but east of Budlake we have certain proof of Trap overlying New Red. It follows, therefore, that the Traps are either on different horizons, or that there is no distinction to be made between the New Red rocks above and below the Trap horizon except where their relations to it are clearly shown. Furthermore, where the relations are absolutely indefinite it is difficult to determine whether the eruptive rock fills a volcanic orifice, conceals a vent, or is the fragment of a lava stream.

It seems highly probable that the volcanic rocks between Rewe and Silverton were connected with the Killerton eruptions, if not from the same vent, from synchronous and neighbouring sources.

IV. SILVERTON.

The mass of Trap on the north of Rewe and Heazille Barton is separated from a smaller patch at the Mill on the east by a narrow valley cut through to New Red rock. The smaller patch was exposed in the lane toward Poundsland, resting on red loamy sand, succeeded by earthy gravels containing no apparent trace of igneous rock and dipping persistently southward. Assuming that the section is unfaulted, it affords evidence of a considerable thickness of New Red rocks under the Trap. The larger mass forms a ridge of higher ground west of Old Heazille Farm (Hazel Barton on the old map), and north of Heazille Barton (Rew Mill on the old map). At the former place, beds of rather coarse reddish brown sandstone dip in a south-easterly direction at 12° near the Trap; as the actual junction was not seen, it is impossible to say whether they overlie or are faulted against the igneous rock. Between the roads near its western extremity the Trap is exposed in a quarry. The rock contains large vesicles throughout, in places showing fluxion lines, the vesicular character is on the whole more pronounced in the upper part, and the rock is more compact in the lower part of the quarry. In one spot an appearance of spheroidal jointing was noticeable, the rock splitting in thin concentric flakes. Red and blackish sand was seen on the top of the northern side of the quarry. It is probable that the Trap overlies the New Red beds on the north, and not improbable that it may be overlain by them on the south. From surface evidence, which is meagre and unsatisfactory, the New Red sands appear to be largely associated with clayey and loamy materials between the Heazille Trap and the Stumpy Cross patches on the north.

At Stumpy Cross and Dunsmoor there are three patches of Trap isolated by denudation and possibly displaced by fault The Dunsmoor patch is exposed in a small quarry near the Farm, but its relation to the surrounding New Red strata was nowhere visible.

The westernmost patch makes a more marked feature than the others, and exhibited definite relations to the New Red rocks in a lane section near its western extremity. The section shows pale grey weathered compact trap overlying friable red sandy rock of rounded grain and splitting in shaly laminæ, which was seen dipping southward near it on the north. On the south the Trap rests on indurated sand-rock, exhibiting an incipient shaly structure below contact. As it is legitimate to assume that these three patches were connected as part of a continuous lava flow we must regard them as outliers probably severed from the Heazille mass by denudation.

The Trap patches of Silverton are three in number. Of these two are very small, viz., near Silverton Park House (Combe Sachville), described by Mr. Hobson, and in the road north of Silverton Park Farm.

Trap was noticed in the middle of Silverton by the road leading eastward from the road junction on the north-west of the church, whence it extends southward for about thirty chains, evidence of its occurrence having been obtained here and there, and in a north-westerly direction probably as far as the hill south of Great Pitt Farm. The Silverton trap in its central mass is bounded by a fault on the west, the prolongation of which forms the eastern boundary of its northern extremity S. of Great Pitt Farm, and of the southern extension by Newcourt. This circumstance no doubt accounts for the abnormal trend of the patch. The only clear section exhibiting the relation of the Trap to the New Red was furnished by a lane to a farm-house in the south part of Silverton. (Fig. 16.)

Here grey Trap rock (4), much decomposed and split up by numerous irregular joints, rests upon (3) Red sand-rock, in places stained blackish and brecciated towards the base, upon (2) Rubbly breccia of angular and sub-angular grit and quartz stones in a coarse dark red sandy matrix, and upon (1) Rubbly breccia with small stones and coarse loamy brecciated sand with intercalated bands of reddish sand. The church is built upon sand and breccia, but Trap was observed at a house adjoining the west side of the churchyard.

The following information was obtained from a well-sinker Mr. Tucker:—

At Mr. Copp's, next door to Church Cottage, a well was sunk through 30 feet of igneous rock.

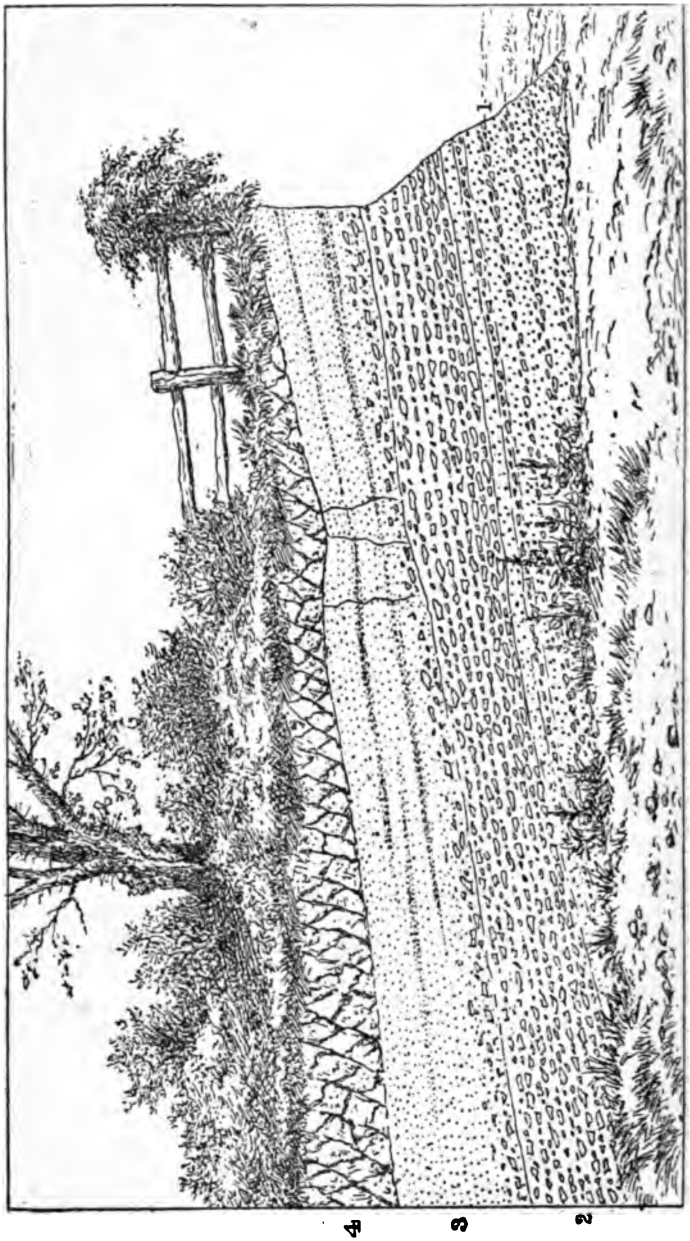

Fig. 16.—*Section at Silverton.*

At Welland's (baker's) shop igneous rock was penetrated to depth of 25 feet.

The blacksmith's (machinist) shop opposite Tiverton Cotta (on 6 inch map) and Mr. E. Thomas's house are situated on the igneous rock.

On the south the Trap may be terminated by a fault. High southerly dips ranging from 14° to 25° were obtained in the breccia by the road north of Stumpy Cross, and an appearance of discordance in line with the termination of the basalt (if not due to redeposit) suggests a fault with low hade. The high dips through presence of false-bedding cannot, however, be relied on. On the north-west of Silverton and south of Great Pitt Farm (named on 6 inch but not on old or new 1 inch maps) on a small hill the Trap is evidenced by surface exposures in a copse. The relations of the sands to the breccias are so irregular that no dislocations can confidently be traced by their distribution so as to account for the position of the small basalt patches. This irregular association will explain the absence of breaks or deflections in the boundaries of the breccia, where faults may cross them, as any such deflections would be theoretical unless the positions of faults were actually witnessed in the vicinity.

South of Red Cross, between Silverton and Silverton Park, a small patch of Trap was exposed in the road section, which is from 8 to 10 feet in height. At three chains south from Red Cross hard red sand-rock on blackish sand with bands of breccia dips under basalt, being altered near contact to a hard whitish sandstone or a blackish sand-rock. The igneous rock was mostly overgrown, especially in the upper part, but at 142 yards from Red Cross breccia was shown overlying it, and evidently let down by a fault, as blackish sand under Trap occurs at the base of the section for 14 yards further. Twenty-three yards further Trap appears to form the section, being cut off by a fault (not exposed) against red sand and clay overlain by Trap evidenced for 12 yards further. Beyond this the section is obscured, so that the southern boundary of the Trap and its relation to red sands and gravelly sand and loam exposed further on are indefinite.

The well-sinker, Mr. Tucker, stated that the igneous rock had been penetrated to a depth of 30 feet at Combe Sachville (Silverton Park on the new map), and was found to rest upon yellowish sand. Enquiries failed to throw any light on the precise locality of the above sinking. It probably refers to the quarry, now a pond (shown on the 6-inch map), from which Mr. Hobson obtained his specimen. This section was visited in 1899. The north face of the old quarry consists of trap; the dip is southward, and at and near the entrance to the old pit the rock is seen to pass under red sandstone, with fine breccia or coarse sand seams, about 5 feet thick. The Trap is more or less vesicular, and in places (as where it underlies the sandstone) is very vesicular. A small fault, shown below a bed shelf, cuts off whitish shaly sandstone on an inosculating mixture of sand and trap (thonstein porphyr ?). On a ledge just above the pond a vein of red grey-spotted rock lined with calc spar occurs in the Trap. The quarry face is much overgrown with ivy, and the estimated thickness of trap above the pond surface in the highest part is not much more than 15 feet. On the north of the quarry there is no superficial evidence of Trap, and there can be little doubt that it is cut off by a fault against breccia, and that this fault in its western prolongation affects the relations of the rocks in the lane north of Silverton Park Farm, south of Red Cross.

On revisiting the lane section the exposures were found to be even less perfect than of yore, vesicular trap being visible in three places only, besides the exposure of its junction with the underlying New Red rock near Red Cross. The surface evidence on the west side of the lane leaves the extension of the Trap towards Silverton extremely doubtful, whilst on the east side its extension towards the Silverton Park quarry is most improbable. Throughout the Silverton area it is not possible to distinguish New Red rock above, from that below the igneous rock horizon, beyond the actual exposures of their relations, but there is sufficient evidence to show that the Trap rocks are high up in the Lower New Red, sufficiently so in fact to permit of their being regarded as practically on the same horizon with the masses round Killerton and near Stumpy Cross and Heazille. The position of the Silverton Traps in the New Red Series is further proved by the absence of any traces of contemporaneous vulcanicity in the steep slopes of New Red breccias, gravels and sands cut through in the excavation of the Exe valley between Silverton and Thorverton, although there are Trap rocks both north and west of Thorverton, and these may well have been connected with those of Silverton.

V. THORVERTON.

The Thorverton traps consist of one rather large mass and two small apparently faulted patches. A specimen obtained near the Farm at the western extremity of the larger, or Raddon, mass was pronounced by Mr. Teall to exhibit the character of an originally altered Ophitic Olivine Dolerite.

West of Thorverton the Trap forms a hill feature extending for three-quarters of a mile to Raddon Court on the old map (the farm south of Raddon Court on the new map). This mass was well exposed in the road south of Lynch, where it rests on red rock-sand, indurated and presenting a greyish and red banded appearance in contact with the Trap, below which it exhibits a shaly tendency. The Trap is vesicular throughout, and in one place exhibits spheroidal structure, the rock flaking off in concentric coats. On the south the relation of the Trap to the New Red sand and loam is not visible.

At the Farm at its western extremity the Trap rests to all appearance upon hard even bedded sandstones dipping south. On the east of the Farm the quarry from which Mr. Hobson obtained his specimen exposed rock of a bluish grey tint to a depth of about 40 feet, but the deepest part of the excavation was filled with water when visited. On the south-western face of the quarry the Trap is overlain by red sands, a fact previously noted by Mr. Vicary.* From this observation it would appear that the Trap passes under the New Red rock on the south, and is therefore intercalated in it either as a lava or sill. In the lane between Lynch and Raddon Court (on the new map) a small patch of Trap is thrown down by a nearly W.S.W and E.N.E. fault; on the north it rests upon hard red sandstone. Following the direction of this fault a small patch of Trap, vesicular and much split up by irregular joints, is visible in the road to Fursdon. It exhibits spheroidal structure on a small scale and is apparently faulted against New Red gravels on the north, but on the south it rests on red sand mottled with large circular buff and grey spots and patches, and dips northward at from 10° to 12°. The sand is altered for 6 inches below contact, presenting a finely vesicular appearance and red and blackish bands. The grey and buff spots are similar to, though much larger than, those so frequently met with in the indurated sands in places inosculating with the Traps.

Conybeare and Phillips† found the igneous rock in one of the Raddon quarries "covered by a sandstone bed of from 3 to 10 feet in thickness. . . . In one quarry at Thorverton, a line of sandy clay not quite a foot thick, prevents their actual contact. At other places, especially at the Raddon quarries, the two substances appear to pass so insensibly into each other. . . . "At the Radden quarries we noticed the occasional tendency of this (the igneous) rock to split into basaltiform balls; and in one spot observed it traversed by nearly horizontal veins of its own substance, differing slightly from the mass by their greater compactness, and the largeness of the nodules which they contained. The veins of extraneous matter were mostly vertical, or at a very high angle."

Whether the Raddon mass and the outlying faulted patches once probably continuous with it were lavas emitted from a strictly local source, or originally connected with those of Silverton is purely conjectural, still more hypothetical is their original connection with the West Sandford and Spencecombe and the Posbury and Yeoton rocks. In either case such connections postulate an enormous amount of denudation, and, if true, should enable one to trace a line between pre- and post-Trappean New Red strata.

VI. CREDITON.

Posbury and Yeoton.

The Traps of Yeoton (phonetically spelt "Uton" on the new map) and Posbury afford clear indications of their relations to the New Red series. The main mass occupies the hill between Posbury and Folly, and occurs in rather a fragmentary manner in its prolongation towards Yeoton. It is separated from the Yeoton patch by a narrow valley cut through to subjacent New Red rock.

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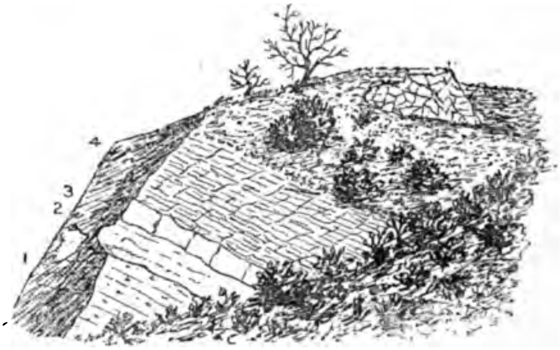
* Trans. Dev. Assoc. for 1865, p. 49.

† Outlines of the Geology of England, etc., 1822, p. 298. See also J. J. Conybeare, Ann. Phil., New Ser., vol. ii., p. 161, and De la Beche's Report, chap. 7, p. 201, footnote, etc.

Near Posbury and at Yeoton breccia with igneous fragments rests on the Trap, and in the intermediate district upon the antecedent sediments, pointing to the irregular marginal termination of lava flows or to very irregular post-trappean denudation, probably to both. A quarry in the Yeoton patch gives a section showing Trap rock (4), split up by numerous horizontal joints into irregular laminæ broken by irregular cross joints. For 4 feet from its base Baron von Reinach, in 1891, recognised the type of the Saxon "Thonstein porphyr," which is a vesicular red and purple rock mixed with volcanic ash and sand. Below is a hard cherty sandstone (3) with finely vesicular lines and patches for 2 feet down from contact with the Trap. Near contact the vesicles are filled with white matter. Under this bed are tough beds of red sandstone (2) upon red sand-rock (1), banded with brownish stripes in places and with a band of nearly angular grit and quartz stones. The dip is S. by E. at an angle of 10°. About 40 feet of Trap is exposed in this quarry. From contact northward to the Alluvium the difference in level is about 55 feet, and may afford an indication of the thickness of the earlier New Red sediments.

FIG. 17.—*Quarry at Yeoton.*

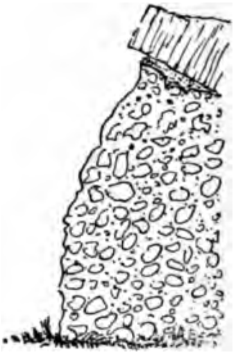


Scale about thirty feet to an inch.

The Posbury mass of igneous rock is exposed in a small quarry on the summit south of Folly, and is evidenced by partial exposures in the upper slopes and by surface fragments. From its north-western boundary to the Culm Measures, the thickness of underlying New Red rock is probably not more than 40 feet, and on its southern boundary about 20 feet. This attenuation toward the margin of a basin of deposit is to be expected.

Near Posbury Chapel a large quarry from 40 to 60 feet in depth, shows a very interesting section. For 3 or 4 feet from the surface Trap rests upon even bedded indurated sandstones, from 5 to 12 feet thick, in a depression, on the sides of which the upper beds successively overlap the lower. The beds rest upon Volcanic Agglomerate resembling the Porphyr Breccia of Germany, characteristic of the Upper Sötern beds of the Permian, according to Baron von Reinach. The agglomerate rests on Trap which forms the base of the section. Mr. Vicary noticed the occurrence of a fine stratified arenaceous rock, altered in the lower part, on the east face of Posbury Quarry.

FIG. 18.—*Section of agglomerate overlain with sandstone and andesite at Posbury, near Crediton.* (Sir A. GEIKIE.)*



In one part of the quarry the agglomerate rests on sandstone.

The southern boundary of the Trap terminates eastward, allowing the newer breccias to rest on the older sands for ten or twelve chains, when they are again separated by a small patch of Trap near Venny Tedborn and Court Barton, which was doubtless part of the Posbury lava. Another patch, once no doubt a part of the Posbury flows, is found at Gunstone (Stockaday on the old map).

The Gunstone Trap, as shown by the lane, is much split up by irregular joints; it is partly mixed up with hard spotted sandstone inosculations, and presents in places the appearance of a volcanic agglomerate. The Trap in one spot is shown resting on tough reddish brown sandstone exhibiting a finely vesicular structure at contact. (See also p. 40.)

This Trap patch is important as indicating the extension of the Posbury and Yeoton flows, from which it is severed by the intervening valley of the river Yeo excavated in Culm Measures. Although it may be said to form a connecting link between the Posbury Traps and those of Spencecombe and New Buildings, and the intervening breccias are largely formed of materials derived from the denudation of the Traps, it is not possible to prove that the horizons were continuously connected, and not improbable that they were emissions from separate vents.

Spencecombe and Sandford.

The Trap patches south of New Buildings are, with the exception of the western termination of the long strip near Spencecombe, embraced in Sheet 325. They are outliers of an evidently once continuous mass, and are doubtless much affected by faults.

Between Knowle, Brandiron Corner, and Spencecombe the chief quarry in the district is found on the summit of a hill, which will be referred to as Knowle (Crediton) hill in contradistinction to the (quartz basalt) Trap of Knowle, near Dunchideock.

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* Ancient Volcanoes of Great Britain, vol. ii., fig. 231, p. 99.

On the six-inch map the quarry is called "Knowle Quarry." It was from this quarry that the specimen, pronounced by Prof. Bücking to be Orthophyr, or Mesokeratophyr, was obtained. A specimen from the same quarry in the Geological Survey collection (No. 957) was described by Prof. Watts as containing olivine in association with orthoclase.

The section in one part showed 40 feet of grey trap, very hard in places and in one part vesicular near the surface, with agates in vesicles. There were no observable fluxion lines, and the joints were lined with a variety of asbestos called mountain leather.

In another place 100 feet of trap was exposed, very vesicular on the south face of the quarry. A tendency to spheroidal jointing without concentric flaking was observed in three places.

In one spot a vertical dyke or vein of New Red material, indurated clay with balls of hard sandstone, was noticed. In the jointing the rock reminded me of parts of the Dunchideock Trap. In three slides from this quarry, basalt, mica trachyte and mica porphyrite were determined by Mr. Teall.

In the lane west of the quarry scoriaceous and very vesicular trap was exposed for about 95 yards, a pipe of indurated clay and sand in one place occurring in it. On its northern border the rock seems to be an admixture of sand and trap of an agglomeratic character, and further north, at the path leading to the quarry, sand and fine breccia are exposed. Near Brandiron Corner a thin strip of Trap, probably faulted, is visible. It is not certain to what extent the New Red rock on the irregular margin of the Knowle Quarry Hill mass is under or over the Trap. As far as the stratigraphical evidence goes the seat of eruption from which the neighbouring Trap patches emanated may have been situated on this hill.

The Knowle strip of Trap is evidently bounded by an east and west fault on the south, and rests on the New Red rock on the north. Its continuity may be broken by denudation, but there is not sufficient evidence to show this on the map. The easterly termination of the strip is almost certainly a fault, which also cuts off the Trap exposed by the lane to Spencecombe and in the quarry near the farm.

The Spencecombe quarry exhibits 30 feet of purple trap rock traversed by thin nearly horizontal whitish veins and crossed by nearly north and south joints lined with asbestos. In parts the rock can be quarried out in large blocks sufficiently hard and durable to be used as an ornamental building stone. In the floor and on the north side of the quarry it exhibits spheroidal structure and in places is coarsely vesicular, and associated with inosculating hard sandstone and trap, in dykes, veins, or contorted beds. The well in Spencecombe farmyard is in New Red breccia below the Trap. Our thanks are due to the owner Mr. Pope for forwarding our investigations in every way in his power. Although the Spencecombe Traps are shown on the map as continuous with the strip by the high road on the south, it is not improbable that they are insulated by denudation.

By the high road east of the turning to Spencecombe a pit, 12 to 13 feet in depth, shows bright red, false-bedded, rather soft rock-sand, with seams of micaceous clay near the base; in one of these, about an inch in thickness, decomposed trap material had been incorporated.

The Knowle Quarry Trap may be connected with the irregular mass between Meadowend (Made end in the old map) and Woolsgrove, but there is no evidence to be obtained in the intervening valley; the same observation applies to a small patch just south of Woolsgrove.

The mass between Higher Woolsgrove and Meadowend may be severed by denudation along a depression on the summit east of Woolsgrove.

In the angle of a field south of New Buildings and at 11 chains to the east of Higher Woolsgrove, the base of the Trap, decomposed and much split up by irregular joints, is shown resting upon felspathic ashy sand and fine breccia, in part rough and yellowish coloured, in part brown. These beds suggest the admixture of triturated volcanic ejectamenta with materials forming before the efflux of the lava. This is the prevalent character of the New Red rocks bounding the Trap patches on the east. The type is well shown in lane sections at Sandford Barton and West Sandford, near Cross, Meadowend, etc. At 6 chains south-east from Higher Woolsgrove, the Trap is exposed by a hedge and exhibits a northerly dip (N.N.W.).

The Meadowend valley insulates the Woolsgrove Trap from the two masses on the summit to the east. Near Ranscombe the most northerly of these patches exhibits the inosculating admixture of Trap and sand so common in the series. The southern mass may be faulted along its northern boundary, but it is not well exposed.

The Sandford Barton or West Sandford Trap makes a hill feature west of the farm; it is exposed near its western extremity, where it exhibits a very vesicular character and some sedimentary admixture. From the depth of the valleys in the tract under consideration, we may infer that the New Red sediments underlying the Traps attain to 100 feet or more in thickness, and are probably much thicker in the more central and deeper portions of the New Red valley.

There can be no doubt whatever that the Traps above described are mere fragments of the original volcanic emissions, and that they were denuded and incorporated in the sediments formed after their emission: but whilst this postulates a large amount of erosion, it sinks into insignificance when we turn to the preponderating quantity of igneous materials in the breccias which cannot be referred to these direct sources of derivation. For the Murchisonite, and granite fragments in the Breccias of Crediton and south of Exeter, the transport of granitic materials from the granite areas exposed by the denudation of tributary streams and carried into the New Red lakes, fiords, or creeks, may be suggested as a possible explanation. The same source can hardly be proposed for the large boulders and masses of quartz porphyry which occur in the breccia. These masses, to have come from the granite area would necessitate conditions little short of glacial. About Ide and throughout the boulder bearing breccia of Teignmouth, the blocks of quartz porphyry are such as would be more readily accounted for by the destruction of intrusive masses in the Culm Measures (in some cases perhaps connected with the eruption of the Traps), than by even short transport from outside the areas of deposition. A small mass of quartz porphyry, apparently intrusive, was observed in the Culm area on the borders of the granite, near Christow. In connection with the Thurlestone New Red outlier in South Devon, there is a patch of andesite which forms the upper part of a pipe in the Devonian, and is irregularly associated with a decomposed acid rock: agglomerate is also present. When we consider the possibility, at all events, of the existence of vents for the Permian lavas in the area now concealed by the Lower New Red rocks; and the probability, almost amounting to certainty, that the cones would be degraded and acid dykes exposed in the area where the crust was weakened by denudation during the formation of the boulder bearing breccias; it requires very little stretch of the imagination to conceive that such igneous constituents as are found in the breccias might be ready to hand without invoking transport from outside sources. Apart from the distance and the supposed superstructure of effusive rocks which the idea put forward by the late Mr. R. N. Worth as to the Dartmoor granite being the stump of a great Permian volcano involves, as Mr. Bernard Hobson says in his fourth reason against the theory, "It is highly improbable that the granite of the core and the lavas of the surface of the supposed volcano were simultaneously exposed to denudation."

2. PETROLOGY OF THE EXETER TRAPS.

BY J. J. H. TEALL, M.A., F.R.S.

The petrological investigation of these rocks is attended with considerable difficulty in consequence of the widespread alteration to which they have been subjected. Much of this alteration appears to date from the Permian period, for fragments of the highly altered traps occur in the breccias and even in the clays, worked for brick-making in the neighbourhood of Exeter. It is highly probable that this alteration is of the lateritic type, so common in tropical regions of the present day, and that it furnished an appreciable portion of the red material of some of the basal rocks belonging to the New Red Sandstone formation.

In consequence of this alteration it is not possible to obtain, even in the largest quarries, such as those of Posbury and Knowle Hill (Crediton), completely unaltered rocks, and the nature of the original magmas cannot, therefore, be precisely determined by chemical analyses.

The rocks consisted originally of orthoclase, plagioclase, biotite, augite, and olivine in varying proportions. Unindividualised interstitial matter appears to have been rarely present. The felspars have often retained their characters, but the ferro-magnesian constituents, with the exception of biotite, have been almost completely destroyed. Unaltered augite may sometimes be observed, but no unaltered olivine has been detected in rocks found *in situ*. The augite has usually been replaced by carbonates, and the olivine by the red decomposition product to which the term iddingsite has been applied, or, in extreme cases, by ferric oxide and carbonate. The common serpentinous mode of decomposition has not been observed in any rock found in place. The prevalent oxidation of the iron-bearing compounds gives a predominant red colour to the rocks—the depth of tint varying with the amount of iron originally present, and the extent of the alteration.

The rocks have been examined at various times by different observers. Mr. Rutley many years ago collected an important series of specimens for the Geological Survey, and his manuscript notes on these specimens, and on the microscopic sections prepared from them, have been of great assistance in compiling the following description. He noted the frequent occurrence of orthoclase, the presence of corroded quartz in some of the basaltic rocks and the affinities of the Killerton rocks to minettes.

Rocks from Spencecombe and Knowle Hill, near Crediton, were examined by Professor Bücking and named meso-keratophyre or orthophyre and biotite-melaphyre with olivine.* Rocks from Posbury, near Crediton, and Pocombe, near Exeter, were described by the same observer as melaphyre with olivine. Dr. F. H. Hatch described the rocks examined by him under the names olivine-basalt or melaphyre, porphyrite and mica-porphyrite (mica-andesite or trachyte).

The most exhaustive account of these peculiar traps which has yet appeared is that by Mr. B. Hobson † who has most kindly forwarded his slides to me for examination. This author describes the Killerton rock as a mica-augite-andesite and places all the other rocks examined by him under the general heading of altered olivine-basalts.

Professor W. W. Watts examined the rocks in the Survey Collection and recognised in one of them the somewhat unusual association of pseudomorphs after olivine and orthoclase.

It thus appears that the observers who have examined these rocks have not agreed as to what they should be called. It will perhaps simplify matters if we recognise the fact that the main object of petrology is not to give names to rocks, but to discover their nature affinities, genetic relations, age, and mode of occurrence.

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* Permian in Devonshire, by W. A. E. Ussher, Geol. Mag.. 1892, pp. 247–250.

† On the Basalts and Andesites of Devonshire, Quart Journ. Geol. Soc., vol. xlviii. (1892), pp. 496

The Exeter traps comprise several more or less distinct types which are connected by transitional forms. Two or three of these types will now be described.

Killerton Type.—The traps which form such a conspicuous feature at Killerton, N.E. of Exeter, vary somewhat in character, but are all closely allied, so far as the nature of the magma is concerned. A specimen from a quarry in the park, on the Silverton side (944), may be taken as typical. This is a porous grey rock, rough to the touch. Flakes of brown mica are scattered though a finely crystalline matrix. Under the microscope the rock is seen to be composed of biotite, iron-ores, and a matrix of microlitic orthoclase. One or two larger individuals of orthoclase occur, but these do not form distinct phenocrysts. The biotites are more or less corroded. Sometimes they have been completely destroyed, and the spaces originally occupied by them are indicated by clusters of opaque grains of iron-ore.

When partial destruction has taken place, the biotite is preserved in the centre, and the margin is represented by iron-ores. The porous character of the rock is strongly marked in the slide, and although some of the spaces merely represent irregular cavities, others probably represent spaces originally occupied by augite.

An analysis of this rock was made by Mr. J. S. Grant Wilson. It is given below, together with the analyses of three allied rocks for comparison.

—	I.	II.	III.	IV.
SiO_2	56·41	55·49	57·55	57·73
TiO_2	1·17	1·78	1·58	—
Al_2O_3	16·42	14·57	13·67	17·85
Fe_2O_3	8·60	8·68	12·86	4·44
FeO	·02	·66	1·17	3·90
MnO	·28	—	—	—
CaO	1·83	·68	1·20	3·65
MgO	2·55	3·61	·52	1·77
K_2O	9·65	7·87	7·77	7·65
Na_2O	2·56	1·86	2·09	3·77
CO_2	·33	—	·62	·09
P_2O_5	—	·27	·15	·15
Ign. less CO_2	·21	3·96	1·45	—
	100·03	99·43	100·63	100·85

I. Biotite-trachyte (Biotite-orthophyre), Killerton Park, Silverton side. (944.)

II. "Cuselit" (Rosenbusch). Dyke in Ottweiler beds, near Winterbach, Rhenish Prussia. Elemente der Gesteinslehre (1898), p. 229.

III. "Orthophyr." Bed in Lower Rothliegende, Röthelgehäu, near Cabarz, Thuringia. E. Weiss. Jahr. d. preus. geol. Landesanst for 1883, p. 235.

IV. Trachyte of the Arso stream, Ischia; contains olivine. "Ciminite" of Washington. Analysis by Fuchs, quoted from Italian Petrological Studies by H. S. Washington, Journ. of Geol., vol v. (1897), p. 354.

The above analyses leave no doubt as to the affinities of the rock. It is allied to the "orthophyres" of Permian age of Rhenish Prussia, the Thuringerwald and France, to the ciminites of Dr. Washington, and to the trachytes of the Arso-type of Rosenbusch. It must be remembered that, owing to the leaching out of carbonates, the specimen analysed probably contains less lime than the original magma, and possibly less magnesia; on the other hand, the ferrous iron has been oxidised.

Knowle Hill (Crediton) type.—Good specimens of this type may be obtained in the large quarry on Knowle Hill near Spencecombe. The upper part of the mass exposed in the quarry is highly vesicular, the lower part fairly massive. It is probable, however, that the whole mass was drusy (miarolitic) for carbonates occur in all specimens, and when these have been weathered out the rock is porous. The more massive varieties consist of small red pseudomorphs after olivine and a few flakes of biotite embedded in a dark greyish matrix. The slightly weathered porous varieties of the same type are lighter in colour and rough to the touch, like trachytes. The upper part of the mass is often as porous as a sponge, and contains large vesicular cavities from which the infilling material has been removed.

When viewed under the microscope in ordinary light a thin section of the massive rock is seen to consist of opaque pseudomorphs after olivine and ragged plates of biotite in a brownish matrix, containing small opaque grains, dusty brown particles, and minute grains or prisms of a colourless pyroxene. Under crossed nicols this ground-mass breaks up almost entirely into an aggregate of orthoclase and a few irregular patches of carbonate, which probably represent the infilling of drusy cavities. The individuals of orthoclase, apart from inclusions, are fresh and of considerable size (1mm.). They are allotriomorphic with respect to each other, but idiomorphic with respect to carbonate.

Plagioclase is quite subordinate to orthoclase, but it occurs under conditions which throw light on the affinities of some of the other rocks of the district. It is found as small microlites in some of the larger individuals of orthoclase or forms, with orthoclase, irregular patches of what may represent interstitial matter. There is no trace of glass, and the original rock appears to have been holocrystalline.

The microstructure of the upper and vesicular part of the mass is different from that described above. Pseudomorphs after olivine and a few plates of biotite occur, but the coarse aggregate of orthoclase is wanting. The felspathic ground mass is microlitic, and the structure of the rock trachytic. The rock has l analysed by Mr. James Grant Wilson.

—	I.	II.	III.
SiO_2 - - -	50·75	50·81	50·78
TiO_2 - -	1·46	1·71	1·32
Al_2O_3 - - -	12·15	15·13	18·70
Fe_2O_3 - - -	9·26	2·40	7·28
FeO - - -	·15	3·52	1.23
MnO - - -	·43	tr.	—
CaO - - -	6·31	4·96	1·57
MgO - - -	6·22	10·64	5·33
K_2O - - -	7·03	7·01	7·36
Na_2O - - -	·55	1·01	1·83
CO_2 - - -	3·76	—	·23
P_2O_5 - - -	—	·62	·22
Ign. - - -	1·78	3·07	4·20
	99·85	100·88	100·05

I. Rock from Knowle Quarry, near Spencecombe (957). Analysi J. Grant Wilson. Sp. Gr. 2.617.

II. Augite-minette with olivine. Dyke; Plauenschen Grund, Dresden. Quoted from Rosenbusch Elemente der Gesteinslehre, p. 22

III. Augite-orthophyre containing olivine. E. Grebe. Erläuterung Blatt Wahlen der geol. Specialkarte von Preussen, etc., p. 33. Analysi Boettcher.

The interpretation of this analysis is attended with s difficulty in consequence of the presence of carbonates, the b of which may have been partly introduced from with Nevertheless it shows clearly that the original magma was p in alumina, moderately rich in iron, magnesia, and possibly li and exceptionally rich in alkalies, especially potash. The si percentage was in all probability slightly higher in the origi magma than in the rock as we now see it, but the differe cannot have been great.

The rock is closely allied to minette and to augite-orthoph as is shown by the two analyses quoted for comparison. upper part, which is trachytic in structure may be termed bio trachyte with olivine; but the term trachyte is inappropriate the main mass. The affinities of the rock with continental ro of approximately the same age are best expressed by the te orthophyre. It is interesting to note that these Perm orthophyres usually contain over 1 per cent. of titanic acid. T fact, and their comparatively low silica percentage are poi in which they differ from normal trachytes.

Pocombe type.—The large quarry at Pocombe presents us w another type of rock. It is composed of numerous red pseu morphs after olivine in a fine grained pinkish matrix. T olivine-pseudomorphs sometimes show the characters of iddi site. The rock is traversed by veins of dolomite with which some calcite is associated. In some portions of the quarry the rock is in the condition of a dolomitic breccia.

Under the microscope the ground-mass is seen to consist of more or less lath-shaped microlites of felspar, a few grains of augite or of carbonate after augite, and particles of iron oxide. Both plagioclase and orthoclase are present, and they vary in relative amount in different specimens. The small and more or less altered laths of plagioclase form kernels in the orthoclase as they do in the absarokites of Iddings.*

The association of plagioclase and orthoclase† is similar to that occurring in small patches in the slides of the Knowle (Crediton) type.

The rock from the Pocombe mass has been termed olivine-basalt by Mr. Hobson, and the term is strictly appropriate to those varieties which contain much plagioclase. On the other hand the specimen, of which a partial analysis was made (953) might more appropriately be termed olivine-trachyte. The average rock appears to be intermediate between these two extremes. It serves to link the types already described with the more typical basalts which have now to be considered.

Ide type.—The rock from Westown Quarry (943), near Ide, may be selected as an illustration of this type. It is a dark brownish rock containing a few small scattered phenocrysts of felspar and grains of quartz, in a fine grained matrix.

Under the microscope the felspar-phenocrysts (labradorite) are seen to be twinned on the carlsbad and albite plans, and to contain numerous inclusions which are often arranged in a zonal manner. The quartz-grains are corroded and surrounded by an aureole in which grains of augite may often be recognised (954).‡ These aureoles are similar to those of the quartz-basalts, described by Diller and Iddings.

Mr. Hobson has described quartz-grains in rocks not only from this quarry, but also from several other localities in the same district. He maintains that they must be regarded as inclusions, and not as intra-telluric products of the basaltic magma.

Pseudomorphs after olivine are not conspicuous in the rock of Westown quarry, but they are not uncommon in other rocks of the same type, although they are never so abundant as in rocks of the Pocombe type. They often show the cleavage and other characters of iddingsite. The groundmass of these rocks is mainly formed of lath-shaped labradorite, small grains or prisms of augite, iron-ores, and carbonates. A little orthoclase is probably also present.

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* Absarokite-shoshonite-banakite series. Journ. Geol., vol. iii., p. 935.

† An analysis of the insoluble portion of a specimen exceptionally rich in orthoclase, was made by Mr. Wilson, with the following result:– SiO_2 61·90, TiO_2 1·89, Al_2O_3 20·61, Fe_2O_3 2·06, FeO nil, MnO ·81, CaO ·66, MgO ·59, K_2O 9·33, Na_2O 1·34, Loss 1·11. Similar analyses of other specimens would undoubtedly show more soda and less potash.

‡ From quarry by Halscombe Farm (formerly called Lower Whitton Farm).

It thus appears that rocks of this type differ from those of the Pocombe type in the presence of small phenocrysts of basic plagioclase, in the comparative scarcity of olivine-pseudomorphs, and in the abundance of labradorite in the groundmass. They are also more massive and less altered. The frequent presence of corroded quartz-grains is another important feature. Although not distributed with perfect regularity it is difficult to obtain a specimen from the Westown quarry which does not show them. They were noted by De la Beche and led him to class these rocks with the "quartziferous porphyries." It is not a little remarkable that we should find, in the Exeter traps, two more or less anomalous phenomena, the association of basic plagioclase with quartz and of orthoclase with olivine, but the former association, as Mr. Hobson maintains, is probably accidental.

We have now to give some account of the distribution of the different types above referred to. The biotite-trachytes appear to be limited to the neighbourhood of Killerton. A specimen from the north-east quarry (947) differs from the one selected for analysis in being darker in colour and more massive. It contains phenocrysts of corroded biotite and pseudomorphs in carbonate after idiomorphic augite in a felspathic matrix. This rock contains also irregular patches of carbonate. Although fresher in appearance than the one selected for analysis it was discarded in consequence of the abundance of carbonates. Mr. A. W. Clayden, Principal of University College, Exeter, has presented to the museum specimens of this type from the following localities:—Old Quarry, 200 yards south-west of Ellerhayes Bridge; exposure on the hillside 300 yards slightly west of south of the above on the 300 foot contour; old quarry 250 yards, slightly north of west of Crabtree: crest of the hill 40 yards south of the *a* of Camp (6-inch, 68 north-east Devon); large quarry by the roadside, 500 yards north of Crabtree; pond 300 yards east-south-east of Killerton. He has also forwarded specimens from Columbjohn Wood, from a quarry 300 yards west of Budlake, and from Beare Farm, all in the same neighbourhood and on the same 6-inch map, but these are of the Pocombe type.

The Knowle (Crediton) type is still more limited in distribution. It is known only at this one locality; but an allied rock occurs in Sheet 310 in the neighbourhood of Loxbear. It is represented by the specimen described by Mr. Hobson from the road side, Long Lane, 1,325 yards S. 28° E. of Loxbear Church. It is possible also that a similar rock occurs at Holmead to the west of Loxbear. No exposure of the trap at this locality can now be found, but numerous specimens have been built into the fences.*

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* One very remarkable specimen (3240) was found here by Dr. Bäckstrom and Mr. Clayden as a loose block. It is a dark, almost black rock, spangled with numerous crystals of black mica. It is composed of more or less serpentinised olivine and biotite with black borders. The groundmass

The rocks of the Knowle type are intermediate between those of the Killerton and Pocombe types, as they contain both olivine and biotite.

The Pocombe type is much more common than either of the two other types already described. The rocks of Northernhay (Exeter), of Posbury, near Crediton, and of Westclist, near Poltimore, belong to this type. The Posbury rock is in some respects intermediate between the Pocombe and Ide types. It frequently contains good phenocrysts of iddingsite, after olivine.

The Ide type is characteristic of the exposures in the neighbourhood of Ide and Dunchideock. Good specimens may be obtained in Westown quarry, near Ide; in Knowle quarry, near Dunchideock; and in a quarry by the side of the road between Dunchideock and the Haldon Hills.

From the foregoing description it appears that the Exeter traps range in composition from trachytes or orthophyres to basalts or melaphyres. The most acid rocks are those of Killerton, and the most basic are those of the Dunchideock district.

There are, however, exceptional rocks, such as those of Knowle (Crediton), which are basic so far as silica percentage is concerned, but which differ from ordinary basic rocks in containing a large amount of potash. These rocks represent effusive forms of the minette-magma, and the Exeter traps are thus brought into relation with the lamprophyre dykes, which are known to occur in Devon and Cornwall, and which are later in date than the folding movements.

The foreign equivalents of the trachytes or orthophyres have already been referred to. They occur on approximately the same horizon at various localities in France and Germany. They differ from ordinary trachytes in having generally a lower percentage of silica and alumina, and in containing over 1 per cent. of titanic acid. The frequent recurrence of these features is sufficient to show either that a common source was tapped over a large portion of Europe during the early part of the Permian period, or, what is perhaps more probable, that similar processes of differentiation operated in local magma basins.

In comparing the Exeter traps with their continental equivalents in age, the fact that they are but feeble representatives of the Permian volcanic episode is strongly emphasised. In bulk they are insignificant in comparison with the Permian igneous rocks of Rhenish Prussia (Saar-Nahe district), the Thuringer Wald and the Grandes Rousses. Not only is the amount of

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consists of minute scales of biotite, minute idiomorphic prisms of augite, granules of iron ore, and a colourless felspathic paste, probably orthoclase. Apatite occurs as an accessory. No rock approaching this in freshness has been found in situ. The rock may be termed an olivine-minette, but there is a sharper contrast between phenocrysts and groundmass than is usual in minettes.

igneous material much larger on the Continent, but the rocks are also of a much more varied character. In Rhenish Prussia, for example, we find quartz-porphyries, porphyrites (andesites) and melaphyres (basalt) in great abundance and rich in varieties. Rocks of the Killerton and Knowle types appear to be comparatively rare. Under these circumstances it is interesting to note that the Permian breccias of South Devon are, as Mr. Worth[*] has shown, much richer in varieties of volcanic rocks than the Exeter traps. Quartz-porphyries, rhyolites, spherulitic felsites, and andesites occur, in addition to the rocks above described. Thus Mr. Worth was doubtless right in maintaining that important volcanoes existed in the West of England when the breccias were formed, although he may have been wrong in regarding the granitic mass of Dartmoor as the denuded stump of one of these volcanoes.

In connection with the view that the trachytic varieties of the Exeter traps are the effusive forms of a lamprophyric magma reference may be made to an important paper by Professor Iddings on the absarokite-shoshonite-banakite Series.[†] Speaking of these peculiar rocks he says:—"They range from rocks rich in olivine and augite with a ground mass of alkali-felspars and ferromagnesian silicates to those with abundant alkali-felspar and mica. Among the first kind is one with a groundmass of orthoclase and leucite; another with a less crystalline groundmass of alkali-felspar, augite, mica and magnetite. These grade into olivine-bearing augite-minettes, kersantites, camptonites, and syenite-porphyry or trachyte. They form a series grading into the normal basalts of the region, and appear from their mode of occurrence to be among the last eruptions of the craters with which they are connected."[‡]

He regards the associated alkali-basalts and sanidine-rocks as "the surface equivalents of certain forms of the olivine-augite-minettes, kersantites, and syenite-porphyry or trachyte." In discussing the relation of the effusive to the dyke forms of the minette-magma he points out that olivine is abundant in the former, and biotite in the latter, and further, that this is a natural consequence of their chemical relations; for biotite may be regarded as consisting of an olivine-molecule associated with a potash felspathoid molecule. That olivine should replace biotite in effusive rocks is also rendered probable by the synthetic experiments of Messrs. Fouqué and Lévy. These observers found that leucite and olivine were formed by the fusion and re-cooling of microcline and biotite.

There can be on doubt that some at least of the Exeter traps have affinities with the rocks described by Prof. Iddings, and it is highly probable that some of the lavas of the Pocombe type would, if the consolidation had taken place under other conditions, have furnished minettes or kersantites.

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[*] The Igneous constituents of the Triassic Breccias. Quart. Journ. Geol. Soc., vol. xlvi., pp. 69-81

[†] Journ. Geol., vol. iii. (1895), pp. 935–959. See also The Origin of the Igneous Rocks," by the same author. Bull. Phil. Soc. Washington, vol. xii., p. 169.

[‡] Origin of Igneous rocks, p. 169.

The Exeter traps have been searched for leucite, but no satisfactory evidence of its existence has been found. It is certain, however, that the conditions necessary for the formation of leucite must have been very closely approached, and evidence of its existence may even yet be discovered.

CHAPTER V.

SUPERFICIAL GEOLOGY.

VALLEY GRAVELS AND ALLUVIUM.

The superficial deposits of Sheet 325 are exclusively of fluviatile or pluvial origin, marking stages in the elaboration of the existing drainage system. Some of the higher gravel patches were doubtless contemporaneous with the raised beaches.

The absence of old gravels in the highlands of the Culm area seems to be due to the streams having been continuously at work in deepening rather than broadening their valleys, whilst in the softer New Red rocks in the districts east of Exeter and between Crediton and Bradninch the converse is the case.

Although "Head" is only shown on the map where débris from the Pebble Beds resulting from the wearing back of their escarpment has been spread over the Marl slopes by rain, similar accumulations no doubt occur both in the New Red and Culm areas, but are superficially indistinguishable from the soil of the subjacent rocks. In the Culm area adjoining the granite, blocks of dolerite are often so distributed as to render it impossible to say with certainty whether they are weathered out *in situ*, or have been slowly lowered by atmospheric waste from masses higher up the slope. Washes of disintegrated granite débris often render the granite boundary indefinite.

To facilitate reference it has been thought advisable in the following detailed notes to give the deposits of each catchment area separately, in the following order:—The Teign and its tributaries; the Exe, the Clyst, and the margin of the Otter catchment adjoining the Clyst; the Culm; the Creedy, and its tributary the Yeo.

The anomalous course of the Exe, traversing the Culm area between Stoke Cannon and Exeter,* instead of flowing round it by Broad Clyst, may have been initiated when the Culm promontory was overlain by New Red rocks, all signs of which have been removed.

The Teign Valley.

The higher terraces of the Teign Valley do not reach 100 feet above the alluvium. At the southern margin of the map, between the Teign and a tributary, a well-marked terrace feature rises to about 50 feet above the alluvium. Near Southwood gravel of Culm stones in loam rests on the Culm Measure shales and grits. The alluvium of the tributary stream interrupts the terrace feature, which is continued for 24 chains northward. Gravelly detritus is evidenced for 16 chains near Venn. At about half a mile further north the terrace feature is again visible, and extends for about three-quarters of a mile northward, breached in one or two places by tributary stream valleys. Gravelly soil occurs on the feature, but no sections were observed Near its northerly termination the terrace may be over 60 feet above the alluvium.

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* *Vide* De la Beche Report on Geology of Devon, etc., p. 21.

On the west bank of the Teign, at its junction with a tributary between Burnwell and Leigh Cross, an old gravel deposit is marked by a flat terrace feature. On the south, near Leigh Cross, a trace of gravel, either the relic of a lower terrace or a wash from above, was met with.

On the south side of Dunsford the steep Culm Measure slopes terminate in an inclined plane, which descends to the alluvium. This is either a Head, or wash of Culm débris, over the alluvium, or a low terrace. On the opposite side of the tributary stream on the west, south-east of Whidley, there is a well-marked terrace of gravelly material at from 10 to 20 feet above the alluvium.

In the area north and east of Dunsford superficial deposits are confined to narrow alluvial or gravel flats in the valley bottoms, and if they exist in higher sites must be effectually concealed by Head or talus.

The alluvium of the Teign consists generally of brown loam and coarse brownish sand beneath which gravel is visible in places.

The alluvial tracts on the granite south of Heltor rock have a disintegrated granite subsoil, often overlain by reddish or yellowish clayey soils, and by peaty matter, suggestive of shallow tarns due to the disintegration of the granite by the ponding of rainwater in surface hollows only partially drained.

The Exe Valley.

The higher terraces of the Exe occupy a much larger surface where the course of the river is in the New Red districts than where it cuts through the Culm Measures, and in this respect the alluvial flats resemble them; there is therefore reason to believe that when the river bed had been grooved in the Culm Measures to within a hundred feet at least of its present position, its old alluvial flats in the New Red and Culm areas presented the same, or even greater, proportional differences in breadth.

Near the southern margin of the map at the turning to Brenton north of Kennford a small patch of gravel composed of rounded and sub-angular fragments derived from the New Red breccia of the neighbourhood, and of angular and worn flint stones, rests unconformably upon the New Red breccia. The gravel is 2 feet thick and is overlain by a redeposit of the breccia, it contains strips of loam. This gravel of the Ken tributary is the only old river deposit observed on the western side of the Exe to the south of the terrace near Alphington. The redeposited breccia overlying it would be quite indistinguishable from the ordinary soil of the district in the absence of sections, it is therefore probable that gravels may occur on the west margin of the Exe alluvium near Exminster which from this cause are not apparent.

From its high tide confluence with the river Clyst to the Culm Measure boundary in Queen Street, Exeter, old gravels of the Exe cover considerable tracts. A narrow strip of gravel consisting of pebbles (whole and broken) and sub-angular fragments of Culm grits and quartz in a brownish sandy matrix, commences near Mount Howe, in the south of Topsham, and extends for a mile and a half northward to New Court Park, whence it is shown on the map over a considerable tract as far as Countess Weir on the west. It is possible that this gravel may be divided into two patches by the depression between New Court and Newport House. The terrace descends from 50 feet, on the east and north, to about 20 feet above the alluvium on the western border. Two patches of gravel between Wear House and Northbrook Park mark its further extension. In the northernmost patch gravel 6 feet in thickness was exposed at the turning to Higher Wear Church. At Northbrook Park the terrace is broken by a tributary valley but is again encountered at the 50 foot contour on the high road to Exeter, whence it is shown covering a large area on the south of the city, although probably as a deposit of recognisable thickness it may not extend as far northward by 10 chains as is shown on the map. At Old Abbey the deposit consists of dense gravel of flat pebbles and sub-angular fragments, mostly Culm grit, under 3 feet of brown loam. At about 10 chains further up, the Exe cliff bank displays about 15 feet of gravel composed of pebbles and sub-angular stones of purplish and bluish grey Culm grits and of quartz.

In all the following observations the similarity of New Red materials, which are of a very impersistent and changeable character in Exeter, to old alluvial clay and gravel must be taken into account, rendering it impossible to tell in some cases whether the surface materials may be *bona fide* river deposits or New Red strata.

A well sinker said that 6 feet of gravel was encountered in sinking at Bellair, a house about 14 chains N.W. of Topsham Barracks. The following from the same source refer to localities in this and in the central parts of Exeter:—At Mr. Baker's Heavitree Brewery a well was sunk through gravelly soil into the New Red series. The small pox hospital is on greyish breccia presumably New Red. Radnor Place is situated on gravel.

At Mr. Stafford's in Friernhay Street an uneven capping of gravel rests on New Red sand.

The late Mr. Linford of Exeter had for some years prior to 1876 jotted down any information as to the New Red strata that came under his notice in excavations made in the city. Although by no means detailed, these observations are of interest where sections are unobtainable. Behind the Almshouses at Barnfield Road, on the slope from the footpath to the brook, an exposure of a bed of alluvial gravel, clay, and fine sand, and clay, and sand of an olive tint, was noted. In this note the clays and sands probably belong to the New Red. By Barnfield Road opposite the Almshouses he observed a thin capping of yellowish alluvial gravel upon (New Red) clay and marl in a shallow cutting.

Mr. Linford kindly furnished me with the following notes of excavations :—

In Queen Street, thick red and buff clay and marl were exposed in excavations for Mr. Roberts's house near the Fishmarket. Whether this referred to New Red in part or altogether was not stated.

At Paul Street an underground passage from Messrs. Harding and Richards' offices was excavated in mottled blue and buff clay upon red gravel and boulders for 15 feet (evidently in New Red beds).

An excavation opposite the Albert Memorial Museum, at Mr. Ackland's, showed yellow gravel and sand, with tolerably large partially-worn stones.

In front of the Museum an excavation 12 feet deep showed gravel of rather large angular and sub-angular stones under tenacious clay, encountered just below the surface, and containing a bed of wet red gravel with smaller stones than those in the bed below.

An excavation made in 1868 at Gard's building, between the General Post Office (since moved to High Street) and the Museum, reached Culm Measures at a depth of 16 feet, under gravel containing large boulders of white crystalline rock, overlain by clay and capped irregularly by gravel and sand towards the surface. The boulders suggest either a rubbly covering of Northernhay trap or of New Red breccia partially derived from it.

A sketch section of a part of the foundations of the Rougemont Hotel, furnished by the late Mr. Parfitt showed gravel averaging 6 feet in depth, in hollows in Trap rock partially lined with clay. It seems, therefore, that the Exeter gravel was deposited on an eroded surface, on parts of which it is very thin or altogether absent.

Mr. Linford noted the following :—At Bedford Lane, near Half Moon Hotel, red sand and marl were exposed. At the back of the Half Moon Hotel an excavation showed yellow gravel, with rather large grit stones at 13 feet from the surface. In Southernhay, by the upper grass plot, gravel containing pebbles and resting upon red sand was exposed. In the foundations of the Congregational church in Southernhay, at the corner of Dixie's Fields, red marl was cut through for 6 to 8 feet; the surface soil is not described. An excavation at Mr. Brand's house, near the Devon and Cornwall Bank in Cathedral Yard, disclosed gravel and New Red sand.

During the progress of the Survey, in November, 1876, between Bedford Circus and the High Street, reddish and yellow clay was exposed to a depth of 2 to 3 feet under 5 or 6 feet of made soil. The clay contains worn fragments of Culm rocks, and appeared to be of alluvial origin.

The foundations of the Board School in Holloway Street, behind Landsdown Terrace, furnished the following section from the surface downward :—

	Ft.
Made ground, about - - - - - - - - -	3
Brown gravel of pebbles and sub-angular fragments of grit, quartz, and occasionally flint, in brown sand matrix. In another part seams of coarse brown and yellowish sand occur in the upper part of the gravel, about - - -	5
Purplish red clay, loam, and loamy sand containing small stones and a few fair sized fragments of igneous rocks and grit.	

The lowest stratum belongs to the Lower New Red series, and continued to the bottom of the excavation; grey sandy intercalations show the bedding. About fifty yards off, within the Schoolhouse enclosure, coarse brown and yellowish sand occurs in the gravel near the surface.

The smaller gravel patch at Higher Summerland Place seems to be little more than a trace of the former extension of the terrace, evidenced by a few surface pebbles and perhaps redeposited New Red materials. The

Exeter gravels are in parts of their extension more than 100 feet above the alluvium, and considerably higher than the gravel terraces of Alphington.

The Alphington gravel terrace rises from the alluvium to from 30 to 40 feet above it. The terrace extended on the west side of Knowle Hill by Matford Barton to Old Matford, but tributary denudation has insulated two small patches on the south of Matford Brook. Gravel 5 feet thick is shown on the south side of Old Matford. The Alphington Terrace gives the following section in a pit between the village and Knowle Hill:—

	Ft.	In.
Grey dusty soil with a few stones in the lower part	2	0
Red-brown gravel with grey streaks, of small angular, sub-angular, and well-worn stones, irregularly alternating with coarse sand or fine gravel and with an impersistent band of coarse and fine yellowish sand	3	0
Reddish brown, locally grey, mottled gravel	2	0
Gravel as above, with larger stones and some rounded boulders	3	0

The stones consist of Culm grit of various colours, and fragments of igneous rocks, some containing murchisonite; and there are a few flint and chert fragments.

In one part of the pit rubbly red grey-mottled New Red breccia with small angular and sub-angular stones is shown beneath the gravel. In places the upper part of the gravel is red, with occasional grey bedding streaks, and in this respect, and in the assortment of dense rubbly gravel with fine gravel or coarse sand, presents a strong resemblance to sections of New Red breccia near Crediton.

Red clay is said to have been encountered in drainage in a depression about a quarter of a mile south of Alphington.

Near Park House a gravel terrace, probably once connected with the Alphington Terrace, commences, and extends for a mile northward, about 30 feet above the alluvium in the highest part. East of Barley House by a path 3 feet of gravel of pebbles and subangular stones of Culm grit of various colours, quartz, and a few of flint, chert and trap, was exposed. With this terrace we pass out of the New Red into the Culm area, in which traces of old river gravel, proving the northerly extension of the terraces, occur at Exwick and Cowley, and on the opposite (east) bank of the Exe in a chain of small patches between St. Davids Station and Barton Place. At Exwick the old river deposit occupies a narrow terrace feature in two patches, consisting of cream-coloured and grey clay and loam, with fragments of Culm shale and grit generally angular.

At Cowley gravel occurs in two patches, in the larger of which a section 3 feet 9 inches deep, showed subangular gravel of quartz and flat grit stones in a red loamy matrix, containing a band of coarse red sand passing horizontally into gravel one foot thick and one foot above the base of the exposure.

On the east bank of the Exe there is a small patch of old gravel at Barton Place and four patches further south, on a narrow terrace feature broken by brook depressions. Between the confluence of the Exe and Creedy at Cowley, and that of the Exe and Culm, old gravels are confined to the northern bank, where they occupy a terrace feature broken by tributary denudation in two or three places. The westernmost gravel patch is 1 foot thick at Pynes.

On the north of the farm between Pynes and Woodrow Barton the gravel of the central patch is exposed in a pit to a depth of 4 feet; the deposit is stained black in places, and composed of flat pebbles of Culm grit of various colours and sub-angular fragments of grit and quartz, flint and chert being apparently absent. Brown grey, yellowish and pinkish mottled clay with angular grit stones occurs near Woodrow Barton.

At about ten chains north of Woodrow, on the west side of the Exe, signs of old river terrace deposits were recognised on Culm Measures, separated by tributary denudation from the well marked terrace, on which Brampford Speke is situated.

The Brampford Speke gravel of pebbles and sub-angular fragments of

Culm grits and quartz rests on the New Red sand-rock in the river cliff at about 30 feet above the alluvium. The late Mr. W. S. S. Gamlen* gave a well section in the village in which the total thickness of the gravel amounted to 13 feet, and the upper part from 3 to 9 feet consisted of sandy loam.

The gravel patch between Willow Park and Yellowford contains large flat worn grit stones and fragments of quartz. This patch was probably connected with the gravels of Brampford Speke on the south, and with the patches east and south-east of Thorverton on the north.

The gravel of the patch south-east of Thorverton was shown resting on the New Red in a shallow pit on its northern margin south of Court Barton.

The irregular gravel patch on the west of Thorverton may have been connected with those on the east, through a bend in the old river course.

In a wood by the Alluvium, east of Courthayes, gravel was shown banked against gravelly New Red breccias, it forms part of a narrow low-level terrace bordering the Alluvium from the Thorverton Valley for a mile northward. The gravel of the Thorverton Valley merges into this terrace, and is probably of contemporaneous origin. The bank of the Thorverton stream on the west side of the road to Fursdon, west of Courthayes, gave the following section from the surface downward:—

Reddish loamy soil.	
Grey loam with small stones and occasional traces of decayed plants - - - - -	1 foot
Gravel of angular and subangular grit stones -	1 foot
Grey peaty loam with fragments of decayed wood and twigs - - - - - - -	from 4 to 6 inches
Gravel of sub-angular stones, stained yellow in places.	

On its eastern margin the Alluvium of the Exe is bordered by a low-lying gravel terrace, which extends from the north margin of the map southward for 5 miles, with a width of about 3 chains at Chitterley, broadening southward to 12 chains at Nether Exe, where its eastern margin is about 12 feet above the alluvium. The surface of the terrace declines southward at about 12 feet per mile. The gravel is overlain by loam and by red clay in places.

On the north side of Burrow farm brown gravel, for the most part well worn and with no apparent traces of bedding, was exposed in a pit to a depth of 6 feet.

By the Exe at the bend south-west of Stoke Cannon red loamy and sandy soil, from 1 to 3 feet thick, overlies gravel of well-worn and subangular grit and quartz stones in a red sandy matrix, which in one part forms a partially consolidated layer.

At 15 chains further north the river bank gives the following section:—

Red and yellowish loam - - -	for 1 foot from the surface
Grey sand - - - - - - -	about 8 inches thick
Grit and quartz gravel, stones mostly well worn, some small.	

The alluvial flats of the Exe generally consist of loam, loamy clay, sand and clay, resting upon gravels so unevenly that gravelly deposits often constitute the surface. Near St. David's Station the alluvial soil is brown loam.

At 10 chains south of St. Thomas Station, between St. Thomas Church and the Railway, a pit section shows the following under a surface of made ground:—

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* First Report of the Committee for investigating the circulation of the underground waters, etc. Rep. Brit. Assoc, for 1875, pp. 117, 128.

Grey dusty soil with flattish grit pebbles and sub-angular stones, 2 to 3 feet thick, upon reddish-brown gravel, mostly composed of flattish grit pebbles.

To the south of the pit the surface undulates slightly; the soil is brown loam.

On the west side of the railway, where the Oakhampton road crosses it north of St. Thomas Station, the alluvial deposits were proved to be 25 feet thick, and to rest on Culm Measures. The sequence in descending order is:—

Earth and gravel.
Olive brown sand.
Small gravel, light coloured.
Gravel of large pebbles, yellow in colour and cemented in places.

Godwin-Austen* recorded the occurrence of *Tellina*, *Mactra*, and *Cardium* in the estuarine alluvial deposits at Princes Nursery, near Alphington. The locality is probably a nursery in the Freehold by the Alphington road, near Princes Square, about a quarter of a mile S.S.E. from St. Thomas Station. The highest point to which ordinary tides now flow up the Exe is half a mile below Old Abbey, about 105 chains south-west from the Nursery. Whether the presence of the shells evinces a recent oscillation in level, as Godwin-Austen suggested, or may be referred to a time when the rainfall was greater and the river course broader and open to tidal influence higher up than at present is not certain, but other considerations adduced by him favour the probability of Godwin-Austen's inference. The alluvium of a tributary stream, near Whipton, at the bend on the south of the Exmouth branch railway, is composed of loamy clay and sandy loam upon gravel of angular grit stones about 1 foot thick.

The alluvium of the streams between Woodbury and Exton is largely composed of pebble gravel derived from the New Red Pebble Beds. These streams are tributaries to the Clyst at low water.

At the south border of the map, south of Exton and over a considerable tract east of Exton, old gravels are spread, also to a great extent composed of debris from the Pebble Beds. A smaller patch of similar gravel is visible near Venmoor Farm, south of Woodbury. The small gravel patch south of Exton is part of a lower terrace on or about the 50-foot contour, which is further evidenced by three small gravel patches between Woodbury Road Station and Ebford. The large gravel patch east of Exton formed part of a higher terrace on or about the 100-foot contour, which may, with the Venmoor Farm patch, have been deposited by the former representative of the Woodbury tributary, or by the Exe. These gravels occupying a sort of border-land between the Exe and Clyst drainage areas, form an introduction to the old gravels, etc., of the Clyst catchment, and have therefore been given here.

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* Geology of S.E. Devon, Trans. Geol. Soc., vol. vi., p. 440.

The Clyst Valley.

The Clyst rises in a pebbly soil upon New Red Marls fringing a Pebble Bed outlier at Clyst William Farm (proper name, according to Polwhele, is Clyst-well Head), East of Plymtree; its course is very tortuous as far as Broad Clyst, whence it flows southward, joining the Exe below Topsham. The Clyst is about 16 miles in length, and its catchment basin is about 55 square miles in extent. The Clyst has given names to most of the hamlets on its banks and to some farmhouses.

The old gravels of the Clyst are seldom well defined on the hills of Lower Marl, owing to the admixture of pebble debris from the Pebble Beds with red clay derived from the Marls on which they rest. It is probable that many more traces of gravels exist than are shown on the map, owing to the difficulty of distinguishing on superficial evidence between an ordinary clay soil and a redeposited clay with patches of gravel. The best marked examples of old river-terrace gravels occur at Mosshayne Farm between Broad Clyst and Pinhoe Stations, near Clyst Honiton and at Topsham. The valley gravels and alluvia of the Clyst and its tributaries are noticeable on account of their breadth, for instance, the alluvia of the tributary draining Broadclyst Moor, and of the tributary streams near Rockbeare, and east and west of Broad Clyst Station, and about Sowton and Clyst St. Mary. Gravels on low-lying lands, as at Marsh Green, east of Clyst Honiton, Rockbeare Vicarage, etc., slope gently to the alluvial flats, rendering boundary lines very indefinite.

The remains of old gravels of the Clyst, probably signs of the northerly continuation of a terrace which included the gravels near Woodbury Road Station and south of Exton, occur just under the 50 foot contour on the east side of the alluvium west of Pound Living (a small patch); at Bishops Clyst near Bishops Court, Dymonds Farm and Marlborough Farm, between the 50 and 100 foot contour. Near Dymonds Farm the gravel consists of pebbles from the New Red Pebble beds resting unevenly on Lower New Red rock-sand. At Waterslade Farm near Clyst Honiton a triangular flat indicates the old terrace level. A small gravelly patch occurs at the 100-foot contour east of Clyst Honiton Church, and a large gravel patch extends from the Church northward descending to the alluvium east of Mosshayne. Relics of old rain washes and of old gravels of tributaries of the Clyst, marking the eastward recession of the Pebble Bed escarpment occur at Bush Hays Farm near Clyst St. George; on the flattish hill top south of Greendale; east of Greendale Barton in two small patches; in three patches near Aylesbeare, in one of which on south-east side of Parkyns Village gravel is shown on New Red sand at from 20 to 30 feet above the neighbouring stream; at Rockbeare House; at Upcott, north of Marsh Green; about half way between Aylesbeare and Clyst Honiton. A tiny patch of gravelly and sandy loam was exposed in a lane on the side of the valley east of Farringdon Church.

East of Pinhoe, on the west side of Mosshayne, an old Clyst gravel is exposed in the railway cutting resting irregularly on Lower New Red sand and 4 feet in maximum thickness; the gravel is composed of quartz pebbles, angular and sub-angular grit, and occasionally chert stones, in coarse reddish brown sand, with reddish buff strips affording rough indications of bedding. The gravel may exceed 40 feet above the adjacent alluvium in places.

The Culm rocks at and near Hornhill, south of Poltimore, are bounded by a wash, or old stream deposit, of reddish and brown clay and loam, with grit stones occasionally worn; in one place by a stream on the north side of a wood 2 to 4 feet of reddish loam was shown on grey clay, with flat, very slightly worn, grit stones on red clay and (in one place) sand. An old terrace gravel of the Clyst, perhaps 20 feet above the alluvium, occurs to the east of Poltimore.

On the opposite side of the alluvium south of Broad Clyst, the hill on which the old windmill stood, east of Black Dog, is capped by gravel and redeposited sand. An exposure showed coarse red sand with buff seams containing flat, slightly worn, polished stones and broken pebbles, firmly bound by the sand and irregularly distributed in it. The sand is distinguishable from the Lower New Red sand on which the deposit rests, by its uniformity in colour, the several grains being red-coated, by its smaller grain, and by its tendency to lamination, also by its cohesive character, causing it to bind in hard lumps in parts.

Gravelly soils are met with about Broad Clyst, probably relics of old gravels in redeposited sand, brown and blackish in places.

A patch of old gravel occurs on the north of Broad Clyst, capping a hill on the east of Broadclyst Moor. East of Broad Clyst, the two gravel patches shown on the map may be connected by redeposited clay with stones over the flattish summit. A road section in the westernmost patch showed pipes of red loamy clay containing small pebbles and flat sub-angular stones of quartz, grit, and a few of flint in stiff red clay, possibly a redeposit. At 3 feet from the surface red clay with grey seams, probably New Red, was shown dipping at 3° in an easterly direction. A note, probably referring to the same road cutting, a little westward or lower down the slope of the gravel plateau, gives the following section:—

Stiff red clay, with pipes or potholes of loamy clay containing stones - - - - - - - - - -	3 feet
Coarse grey rubbly bed - - - - - - - -	3 inches
Red sandy bed, splitting irregularly - - - -	6 inches
Red breccia of stones, mostly igneous in a sandy matrix	5 feet.

The locality was recently (1900) revisited, but this part of the section is no longer visible. There are, however, signs which point to an intercalation of sandy materials in the base of the Marls.

Between Laxbrook and Churchill Farms, east of Broad Clyst, at and above the 100 foot contour the New Red Marls seem to be covered by a redeposited soil with pebbles. At Ebury Farm there is a pebbly patch from 6 to 7 inches thick, and a smaller patch at Godfrey's Farm.

At Norman's Green on the Culm and Clyst watershed there is a gravelly patch on the New Red Marl. A low terrace borders the Clyst alluvium at Newcourt Barton (near Topsham). A pit in it near the river bank showed brownish gravels of quartz and grit pebbles and sub-angular stones in brown-red sand compacted in places. Similar low terraces border the alluvium south of Sowton, near Dymonds Farm, north of Clyst Honiton, east of Broad Clyst Station, at Rockbeare Vicarage, and near Waterslade and Southwood Farms (east of Clyst Honiton).

The alluvium of the Clyst between Broad Clyst and Pinhoe consists chiefly of redeposited sand and clay. The alluvium of the tributary near Denbow Farm, west of Farringdon, gave the following descending section in a bank 3 feet deep:—

Red clay splitting vertically.
Gravel of whole and broken pebbles and nearly angular stones, some flattish, in red sandy clay.
Red clay mottled with occasional grey spots.

By the Whimple tributary, at nearly a mile west from the church, an irregular patch of gravel was shown in red clay. The gravel about 2 feet in thickness, consisted of whole and broken pebbles, derived from the New Red pebble beds, with occasional sub-angular weathered fragments of flint or chert. In this and other cases the broken pebbles have the fractured edges, sometimes angular, sometimes slightly bevelled by attrition.

South of Clyst St. Lawrence Church the Clyst alluvium as shown in the river banks consists of red clay and consolidated loam passing downward into tough grey clay, containing small fragments of Culm shales and stones of grit and quartz disseminated through it. From the Culm Measures the valley bottom slopes gradually downward to Stooke Bridge, although coloured as alluvium, it seems to be more or less gravelly, and may be a low terrace composed of angular and sub-angular stones, derived directly from the Culm Measures, and of pebbles of quartz, quartzite, and hard dark grey quartz veined rock, derived from the New Red pebble beds. By the road near Little Barton Farm a bed of partially consolidated gravel occurs in the clay, suggesting a fragment of an old Clyst gravel, above Stooke Bridge.

The scattering of pebbles in and over rainwashed clay forming the soil of the New Red marls on the slopes below the pebble bed feature between Woodbury and Aylesbeare Common, accounts for the presence of nests of pebbles here and there along the courses of the tributary streams, and other redeposits too insignificant to show on a map.

Roughly speaking, the tributaries of the Clyst drain the escarpment slope of the Pebble Beds, those of the Otter its dip slope. The watershed boundary, however, does not coincide with the present outcrop of the Pebble Beds, some of the Otter tributaries having been initiated when the Pebble Beds extended further west, as, for instance, the Hawkerland stream, the streams on the east side of Aylesbeare Common, on Venn Ottery Common, on the south of Straightgate Farm, and immediately south of Talaton.

By the combined effect of meteoric disintegration and surface drainage the Pebble Beds have not only been worn back, but have been shorn from the summits of their feature over considerable tracts, as on Aylesbeare Common and south of it, and north east of Straightgate. In all these cases the Marls are more or less concealed by Pebble Bed *débris*, which has been shown on the map; from the summits this soil descends the slopes. In the vicinity of Straightgate, or Straightway Head on the old ordnance map, the Pebble Beds themselves appear to be capped by their own redistributed materials to a depth of several feet in places. Whether this is due to surface disintegration and displacements by percolation or to ancient river or stream redeposition is not apparent, and it has therefore only been shown on the map where there is reason to think that the redistributed materials rest on the underlying Marls, not on Pebble Beds. Where Pebble Bed *débris* rests on the overlying Sandstones, as at Baker Brake and south of Stowford, and in the small patches east of Stonyford and at Goosemoor, it is evident that the material must have been transported down the dip slope either by ancient rain wash or fluviatile agencies.

De la Beche * figured a section of a quarry near the London Road on Straightway Hill in 1834, of gravels derived " from the red sandstone conglomerate on which they rest, mingled with some sands." He suggested that the disintegration of the red conglomerate might have been contemporaneous with the disintegration of the Chalk and Greensand which resulted in the formation of the lower part of the Plastic Clay series (now regarded as Bagshot Beds by Mr. C. Reid). Whatever may be the age of these gravels there is no doubt that their occurrence complicates the relations of the Marls and Pebble Beds north of Straightgate Farm where they are indicated as Head or Wash on the map, as it is uncertain whether they are a thin soil of Pebble Beds on the Marls or a wash spread over the Marl from the Pebble Beds on the west. On the north of West Hill Church gravel is shown on the map: in this case the gravel contains chert as well as Pebble Bed pebbles, and may conceal sandstones faulted against Pebble Beds and must be regarded as an old river gravel. Whether mere washes down the dip slope aided by surface disintegration or ancient river gravels their position entitles us to regard these materials as within the catchment of the Otter.

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* Report, p. 396.

Except where it traverses the Culm inlier the watershed boundary between the Clyst and Culm is on comparatively low ground.

The Culm Valley.

Traces of old gravels of the Culm, or its tributaries north of Plymtree, are represented by dark brown clay soils with chert stones occupying the flat topped summits of the low hills of New Red Marl on either side of Higher Weaver and at Dungeons Farm.

South of Westcott a large gravel patch marks the old junction flat of the Culm with its tributary. Near the turning to Tye Farm, in the east part of the patch, gravel of mostly well worn chert, quartz and grit stones in a sandy matrix was exposed in a pit, to a depth of three feet, under a foot or two of reddish and blackish loamy soil. Near its southern margin on the north of Garnshayes Farm a gravel pit showed 5 feet of well worn and subangular grit and chert stones in fine gravel of the same composition, with a nearly horizontal lenticular patch of coarse brown sand which forms the only indication of bedding.

The railway cutting between Hele and Silverton Stations shows an old gravel of chert stones and fragments derived from New Red breccia upon about 20 feet of New Red sand. The gravel is evidenced by chert fragments and brown or drab soil. A redeposit of breccia on the slope north of the cutting, seems to overlap the junction of the New Red sand and breccia.

Owing to the rubbly nature of the New Red breccia it is extremely difficult to distinguish old gravels north and west of Silverton Station. North of the station the brown gravelly soil capping the New Red sandstone may be redeposited or breccia *in situ*, and the same might be said regarding the two patches on the summit north of the Heazille Farm Trap. Near Poundsland and at Heazille Barton there are two small patches, apparently remnants of an old terrace deposit. The gravels shown on either side of Dunsmoor are probably washes.

An old terrace gravel caps the New Red sandstone at Rewe. As shown by the lane near the church, the gravel consists of grit, quartz, flint and chert, stones often well worn, in a matrix of brown sandy loam. The finer varieties of grit and the chert stones often exhibit flat polished surfaces with bevelled edges. One grit stone was 6 inches in breadth and a foot long. This is probably an old confluence gravel of the Exe and Culm.

A low-level terrace commencing at Culm Vale flanks the alluvium opposite Rewe for about two miles ; it slopes gently upward from the alluvium in places, elsewhere making a slight feature.

The low tract west of Beare Farm and a strip of low ground bordering the alluvium from Beare northward may be a continuation of the low terrace. On the opposite side of the alluvium east of Bradninch there appears to be a low gravel terrace of redeposited breccia extending for some distance northward from Kensham Mills.

The flat tracts shown as alluvium between Langford and Dungeons Farm seem to be redeposited Marls. The streams also south and east of Silverton here and there drain flattish bottoms, apparently alluvial and wholly incommensurate with their size.

The Creedy Valley.

Next to the Clyst the Creedy and its tributaries drain the largest area in Sheet 325, being nearly fifty square miles. This river is remarkable for bifurcations; near Downs Bridge it is joined by the Yeo, which although nominally a tributary, has a longer course, and drains a larger area than the Creedy above its confluence with it. The Creedy is joined by the Holly water above Upton Hellions.

As in the case of the Clyst and Culm, the alluvial bottoms of the tributary streams are often of much greater extent than their present insignificance would suggest, and the remains of old river terraces are most considerable in the sandy and clayey New Red districts, and least in the Culm Measures.

An old river Terrace, nearly three miles in length, has been split up by tributary denudation into six patches of gravel, which cap the New Red slopes at 20 feet or more above the alluvium on either side of Newton St. Cyres station. The largest patch seems to stretch for a mile northward from Winscott Barton; it was once probably connected with a gravel patch at Nettacott, and denotes the old confluence of the Efford and Nettacott stream with the Creedy. The gravel patch on the east of Newton St. Cyres station is capped by cream coloured clay and rests on New Red sand at about 20 feet above the adjacent alluvium.

The accompanying interesting section (Fig. 19) of the gravel patch between Newton St. Cyres Station and Lake was exposed in the lane on the north side of the Railway.

The gravel patch west of the above consists of grit and quartz stones in brown loam, apparently 5 or 6 feet thick, resting on New Red sand and fine breccia, in places at about 30 feet above the alluvium.

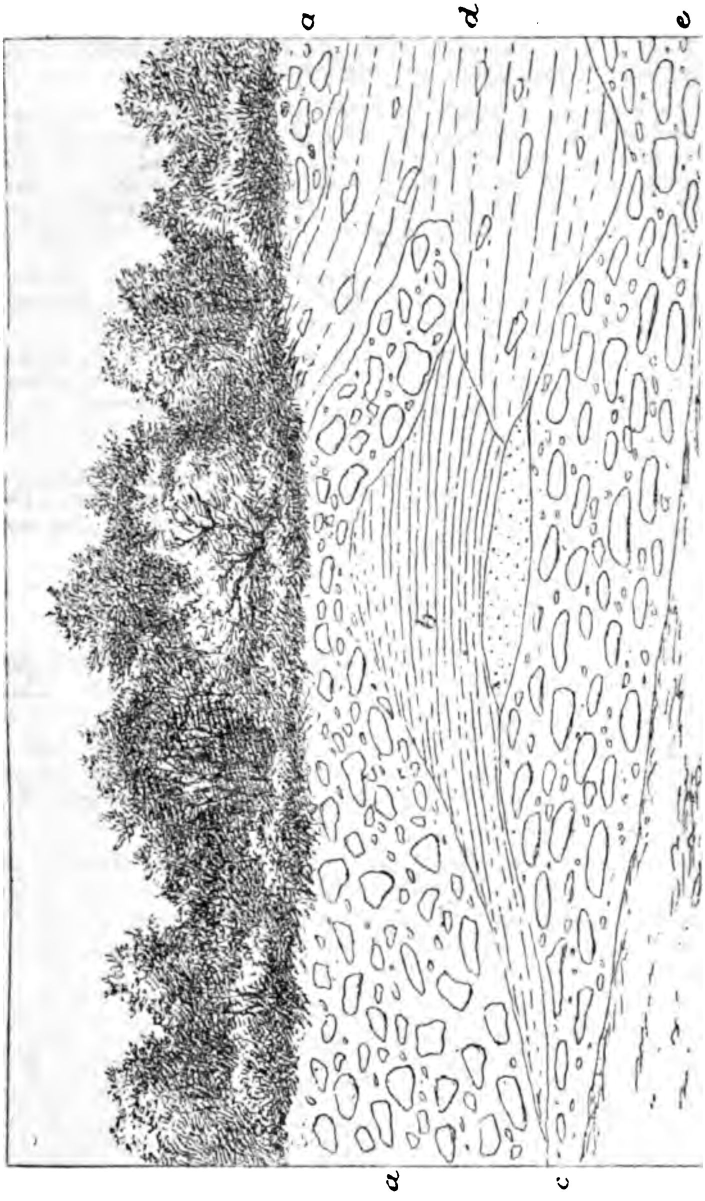


FIG. 19.—*Section near Lake, north of Newton St. Cyres*

a Sub-angular and pebble gravel of grit and quartz stones
brown loam, from 1 to 3 feet thick.
b Red loam, 1 foot 6 inches.
c Red sand exhibiting false lamination.
d Red loam with angular, sub-angular and well worn stones d
tributed irregularly through it, 4 feet.
e Gravel of sub-angular stones and pebbles of grit and qua
in a matrix of fine gravel, resting on New Red sand at ab
40 feet above the alluvium.

The gravel at Creedy Barton is 6 or 7 feet thick and occurs at heights of from 15 to 35 feet above the alluvium; it rests on New Red breccia.

The only patch of old gravel encountered on the south of the Creedy alluvium occurs by the high road west of Newton St. Cyres and furnished the following section, in descending order:—

	Ft.	In.
Fine red brown gravel of sub-angular stones derived from the New Red breccia	1	0
Buff brown loam, splitting in cubical fragments	1	6
Pebble and sub-angular grit stones, usually of a greenish grey colour, in a matrix of fine gravel. This gravel in an adjacent exposure consisted of flattish sub-angular grit stones of average size with lenticular seams of brown sand	2	0

In the railway cutting near the confluence of the Yeo and Creedy the New Red breccias have an irregular capping of buff sandy loam in places, possibly an old river deposit.

The alluvium of the Creedy is flanked on the east, for two miles below Upton Hellions, by flattish ground sloping towards it, and probably an old alluvial low-lying terrace. By the lane just north of Haske there appears to be gravel of redeposited breccia; in one place the stones were found to be cemented by ferruginous infiltration; the gravel rests on light red sand and dark red loam and clay, which may also be redeposited New Red strata.

At Merrifield the soil consists of red clay with sub-angular grit stones. In the orchard on the east of Creedy Bridge a pit (in 1875) showed 6 feet of red loam, with sub-angular stones exhibiting no signs of stratification; the ground rises gently from the alluvium.

There may also be a low-lying alluvial terrace at Aller, west of Sandford, and south of Long Barn, near Creedy Bridge.

The Yeo Valley.

The alluvium of the Yeo and Culvery is bounded by a gravel terrace extending from Kersford to Culvery Bridge, and rising to heights of 15 to 20 feet above it. Its further extension up the Culvery is evidenced by three patches. Near Culvery Bridge the gravel is largely composed of redeposited materials, and might easily be mistaken for a New Red deposit.

The following section was obtained:—

	Ft.	in.
Brown loam, with small stones derived from New Red breccia	2	0
Small angular and sub-angular gravel derived from the breccia, in red loam	2	0
Impersistent seam of gravel of flat grey and brown grit stones, with bevelled edges, at base about 10 feet above the alluvium	0 to 1	0

The deposit rests on red breccia, apparently not redeposited. A small patch of gravel occurs at Uton (Yeoton on the old map, phonetically spelt on the new).

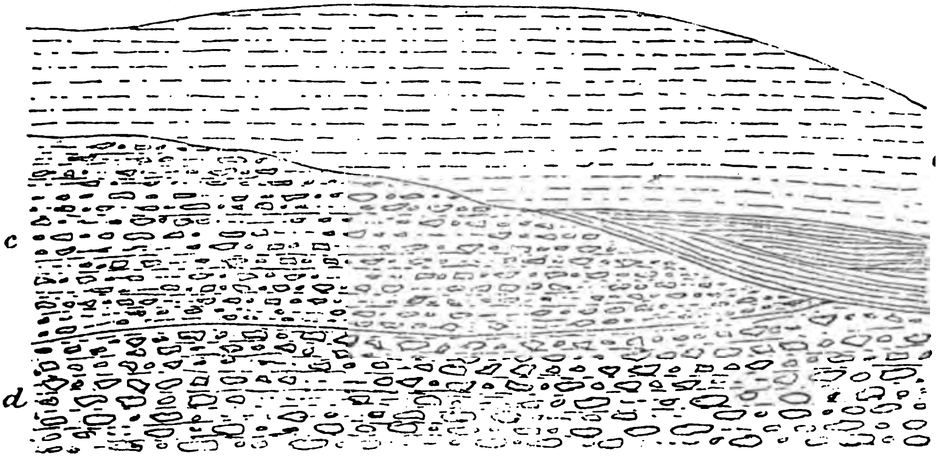
The railway cutting north of Folly exhibited 7 feet of clay, red in the upper parts, passing irregularly into grey and brown tints in the lower, and containing angular and sub-angular grit stones scattered through it. This is probably Head or Wash, but may be mingled with old river deposits. Further west a gravel terrace commences at the mills and continues westward for 50 chains. East of Yeoford the alluvial boundary is very indefinite, also on the north-east of Folly, and in both cases low-lying terraces may border it, but this has only been indicated in the former instance, as the low-lying ground is of some extent, apparently composed of grey and reddish clay and loam, with sub-angular grit stones, and in places it makes a low bank or terrace feature.

Between Gunstone and Folly, at the lane to Moor, the Yeo banks give the following section in downward succession :—

	Ft.	in.
Light buff-brown loam	2	6
Light buff-brown loam with lenticular seams of fine gravel	2	6
Fine gravel seams, impersistent	0 to 1	0
Coarse gravel of sub-angular and slightly bevelled grit and occasionally quartz stones	2	0

At the mills south of Gunstone the accompanying is a section of the Yeo bank :—

FIG. 20.—*Section by the River Yeo at the Mills, south-west of Crediton.*



a Red brown loam.
b Grey and light brown clay.
c Fine gravel in red brown loam.
d Angular and sub-angular grit gravel in red brown loam.

The river bank is 6 feet in height.

The banks of the River Culvery afforded many interesting sections. At Culvery Bridge the section is as follows :—

	Ft.	in.
Yellowish brown clay	2	6
Bluish grey clay, with flat bluish grey grit stones with bevelled edges	0	8
Sub-angular grit gravel in brown loam and clay	3	0

The banks of the tributary brook north of Trowbridge showed the following sections :—

	Ft.	in.
Brown clay and loam	2	6
Yellowish clay and loam	1	0
Impersistent blue clayey seam	0 to 0	4
Brown gravel, angular and sub-angular stones of various sizes, with fragments of drift wood here and there	4	0
Bright red breccia, possibly a redeposit.		

Near the above the opposite bank exhibits the following section :—

Brown loam.
Blue and drab clay.
Blue clay.
Fine gravel.
Brown gravel, flat stones.
Coarse and fine yellowish brown gravel.
New Red breccia with small stones.

In another place the bank consists of cream coloured and buff loam; on a seam of blue clay; on light brown gravel of grit stones of various sizes; on brown gravelly loam with an appearance of false bedding; upon New Red breccia or redeposited breccia. The alluvial deposits are not 6 feet in thickness.

The bank of the Culvery at about 20 chains above the tributary afforded the following section:—

	Ft.	in.
Gravel of sub-angular stones in drab sandy loam, blackish at base	1	2
Light-brown gravelly loam with small shale fragments	0	6
Gravel of rather large flat sub-angular grit stones and of quartz, in bluish clay for a foot from the top, below that in brownish loam, in places containing small stones and becoming an earthy sand	4	0

Near the above the section shows the following succession:—Brown loam with rootlets near the surface extending horizontally and branching downward; on yellowish gravel of grit and rather small shale fragments; on gravel and sand, partly false-bedded; on drab and blackish gravel of flat grit stones and quartz fragments with seams of finer gravel, resting unevenly upon New Red breccia exhibiting grey mottling.

Near the above and higher up, the bank is nearly 5 feet high, and consists in descending order of:—Brown loam, bluish and yellow clay, yellow clay, blue clay, gravel of flat grit stones (some large), and bright red clay, either New Red *in situ* or redeposited.

Near this the bank is 3 feet 6 inches high, and presents the following section:—

Brown loam.
Impersistent seam of bluish clay.
Gravel of flat grit stones in buff and brown clay.

North of Yeoton (Uton), near Yeoton Bridge, the bank of the Yeo is 4 feet in height, and gave an interesting section of brown loam, blackish stained gravel, finer in the upper seam; brown gravel and sand, and buff clay. The gravel is mostly composed of sub-angular Culm grit stones, but fragments of Trap and of New Red sandstone occur sparsely through it.

At West Town, in the south part of Newton St. Cyres, the Shuttern Brook, a tributary of the Creedy, afforded the following section:—

	Ft.	in.
Yellowish and buff loam	4	0
Brown grit gravel	5	0
New Red sand, shown in one place by the stream bed.		

At a mile higher up the Shuttern Brook, buff brown clay rests on gravel of angular and very slightly worn grit and quartz stones and fragments of shale, with no persistent lie, in bluish and brown clay.

A tributary stream west of Newton St. Cyres, at nearly a mile up stream from Smallbrook, showed brown and buff-brown gravelly clay, with angular and bevelled grit stones, resting upon New Red breccia.

The alluvia of the tributaries north of Newton St. Cyres and north and north-west of Crediton call for no special notice, and seldom afford sections of sufficient depth and variety to be interesting.

CHAPTER VI.

ECONOMIC GEOLOGY.

WATER SUPPLY.

As regards water supply the Culm rocks, although more or less favourable, through the association of grits and shales, for yielding small supplies, yet through their numerous contortions and the small dislocations affecting them they are unsuitable for obtaining a large supply, such as might otherwise be obtained in alternations of undulating or gently inclined permeable and impermeable rocks. The New Red beds, on the other hand, might be expected to yield a large supply, by boring through the Marls or Pebble Beds east of the Clyst Valley to the south of the Culm inlier, as they overlie a permeable series of sands or sandstones, which cover a considerable extent of the surface and rest on the Heavitree breccias.

With some exceptions, it is difficult to obtain reliable sections of the strata penetrated in well borings in the district, and as regards the Red Marl area above alluded to, no deep wells seem to have been sunk. Unfortunately no cores were kept of the deep wells in the Culm Measures at the Exeter breweries, and in view of the mention of layers of Trap at 100 feet from the surface in the City Brewery well, this is the more to be regretted.

Exeter Water Supply.

"According to Isaacke attempts were made as early as 1635 to introduce river water into the city, but all ended in disappointment. Within sixty years later the long contemplated scheme was determined upon, to convey the Exe water by wooden pipes to the houses of such of the inhabitants as should agree to take in the same at a reasonable rate. On February 12th, 1695, 'a contract' was made 'for this purpose.'" . . . . "We can well remember how inadequate was this supply—what leakage there was in the wooden pipes, the stoppages during floods and summer droughts." In 1808, Mr. J. Goldsworthy became lessee of the water works—he increased the power of the engine, substituted iron for wooden pipes, cleared the springs that had been choked, sank the wells deeper and laid conducting pipes at the bottom instead of the surface of the wells, by these means securing an ample supply.* Dr. Shapter † says, "the ancient conduits which partly supplied the city of Exeter and the supply to the Cathedral Close houses were derived from springs. The water is particularly good, being clear, transparent, tasteless, and inodorous, sp. gr. 1·002; temperature, 53°, with a varying degree of hardness of from 10° to 25°; contains free carbonic acid, muriate of lime, sulphate of lime, carbonate of lime, sulphate of alumina." "Parker's Well" (very near the Topsham Road turnpike. Polwhele), "formerly in estimation as a holy well . . . . . in the parish of St. Leonards, together with several others of the neighbourhood, do not essentially differ from the above." "The water of a well in the cathedral yard is sparkling, clear, transparent, inodorous and slightly styptic to the taste; sp. gr. 1003; temperature 52°; contains free carbonic acid, muriate of iron, muriate of lime, sulphate of lime, sulphate of alumina, carbonate of lime."

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* From "The History of the City of Exeter," by Rev. G. Oliver, 1861, pp. 149, 150.

† Climate of S. of Devon, 2nd edit., 1862.

Polwhele[*] mentions St. Sidwell's Spring, just above Hill's Court, as "a pleasant water moderately impregnated with iron." He says, "To the water which issues from the Northernhay rock below the castle at Exeter, great virtues are imputed. This spring is never dry at any season of the year. But the water with which the Bedford buildings are supplied is a remarkably fine spring—the most salubrious perhaps in Exeter." The Northernhay or Lions Holt[†] spring is about 126 feet above sea level. The yield is 47,000 gallons in twenty-four hours. The water is conveyed to various parts of the city and distributed by means of drinking fountains. Analysis by Mr. Perkins of Exeter showed that 100,000 parts contain—

Free Ammonia	·004
Albuminoid Ammonia	·0074
Nitrogen as Nitrates or Nitrites	·236
Chlorine	5·7

The St. Anne's[‡] well or spring at Lions Holt was cut into by the London and South Western Railway, but may now be seen on the Exeter side of the tunnel mouth near Queen Street Station. "To supply the conduits of Exeter the authorities directed that a water ram should be erected on the opposite bank of the railway so as to give, as far as possible, a supply to the conduits the same as before the line was cut."

Mr. Thomas Andrew, F.G.S., in a paper on "The Geological Phenomena of Exeter and its Neigbourhood," printed for private circulation, records the observations which from his long connection with the Municipality of Exeter he had exceptional opportunities for making. From this paper the following quotations are taken:—

"From the South Western Railway Station to the bottom of Exe Lane, along what was formerly the brook, then around the Bonhay Road to Fore Street Hill, and thence by Fore Street Hill to St. Stephens, an area will be described which under modern accumulations has a stratum of clay from 2 to 4 feet thick of a yellowish colour and very tough, and beneath this the Carbonaceous shale commonly called 'Shillet.' This shale on exposure to the air becomes soft, and being well worked with water makes a very tough clay. In digging wells in this rock the depths at which water is obtained differ very extraordinarily. A well has a good supply at the depth of 9 or 10 feet in one place, while others not 20 yards off have not had water at less than 50 or 60 feet.

"From St. Stephen's Church to St. John's Hospital, including Bedford Circus, the substratum is of sand and gravel. This is followed by clay mixed with small masses of the stony stratum of the castle, and the masses becoming larger and more compact soon form a rock of the same kind. The wells in this area are from 20 to 30 feet deep, and give most excellent water, which arises from under the rock. The well water of this locality is far preferable to that of the shale.

"Above St. John's Hospital and Longbrook Street the second stratum is a fine red sand about 60 feet thick. Under this in some places is a bed of soft marl from 4 to 6 feet deep, and then again the red sand. The sand extends all over St. Sidwell to the Blackboy Road Turnpike Gate. The soil of the adjacent fields has been for a century and upwards used by the brickmakers. The quarrymen at Heavitree assured me that quarrymen who formerly worked in the quarries there, point to a spot some 30 feet beneath the 'deads' where they came to the bottom of the rock, and that immediately underneath was a deposit of clay similar to that of Polsloe."

Mr. Parfitt[‖] gives a section of the boring at St. Anne's Brewery in North Street at the back of Barnstaple Inn, at about a quarter of a mile from the River Exe at Head Weir, begun in March, 1879, and carried to a depth of 305 feet through Culm rocks without any gravel capping:—

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[*] History of Devonshire, pp. 15, 16.

[†] British Assoc. Rep. Com. Underground Waters for 1879, p, 157.

[‡] E. Parfitt. Trans. Devon Assoc., 1880, vol. xii.

[‖] Trans. Devon Assoc. for 1880, vol. xii.

Common Carboniferous Shale	to 80 feet from the surface.
Rounded white and red quartz grains	at 86 feet „ „ „
Fine flakes of mica imbedded in bluish sandy mud or clay	at 90 feet „ „ „
Some hard beds of very compact shale with large ferruginous nodules penetrated from 96	to 100 feet „ „ „
Soft shale	at 106 feet „ „ „
Another hard band	at 112 feet „ „ „
Dense dark blue shale difficult to work alternating in hard and soft bands.	
Bright ferruginous shale - struck	at 180 feet „ „ „
A fissure.	
Bright red gritty shale not very thick	at 204 feet „ „ „
Again in dark blue soft clay	at 210 feet „ „ „
Below this alternate layers of very hard and soft tenacious clays or shales were encountered - to a depth	of 280 feet „ „ „
Thin band of very red soft shale with a thin band of very gritty clay called by the workmen water sand.	
At 305 feet the boring was suspended.	

This boring is about 33 chains N., of the City Brewery well.

The account in Mr. Martin's Note-book of Well sections, of St. Anne's well boring by Shepheard and Co., March to September, 1879, gives a total depth of 313 feet 3 in., made up as follows:—

	ft.	in.
Red Shale	70	6
Stone	2	6
Blue Shale	9	6
Stone	3	9
Blue Shale with stone intermixed	149	6
Blue Clay	54	6
Sand and Water (? Sandstone crushed by boring)	5	0
Blue Clay with Stone intermixed	18	0
	313	3

Mr. Martin records a well at Bradninch Place, Gandy Street, sunk to a depth of 45 feet with a diameter 4 feet 3 inches. Water rose to 10 feet 6 inches from the surface. No geological details are given.

The boring of the City Brewery well,* near Exe Bridge, at about 25 feet above Ordnance datum was begun in 1846 and completed in 1849. The shaft for 70 feet from the surface is 4 feet in diameter, below it a boring with 4-inch bore was carried to a depth of 270 feet from the surface. The strata penetrated are given as follows:—

	Feet.
River gravel	15
Shillet or Carboniferous shale	85
Alternate layers of trap and red shillet	54
Blue shale	90
Water, sand	3
Blue shale	23

The yield is given as 4,000 gallons in 24 hours.

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* The section of the City Brewery well, kindly supplied me by Mr. Pring of the City Brewery, and that in Mr. Martin's note book are identical with Mr. Parfitt's account as given here

Analysis showed :—

		Grains
Organic and volatile matter including ·112 of oxidisable organic matter		1·15
Total solid matter per gallon, dried at 270° F.	Oxide of iron and alumina with traces of phosphoric acid	·15
	Sulphate of lime	6·24
	„ „ magnesia	·48
	Nitrate „ „	·99
	Cloride of sodium	4·79
	Carbonate of soda	9·75
	Soluble silica	·10
		23·65

Dr. Shapter gives an analysis of the water by Mr. Herapath, of Bristol, as follows :—" In an imperial pint there are of

Chloride of magnesium	a trace.
Soda, with a vegetable acid	0·44 grains.
Muriate of soda	0·48 „
Sulphate of soda	2·96 „
Carbonate of magnesia	2·60 „
Sulphate of lime	0·86 „
	7·34 „

On the south side of Exeter at 50 yards from the Exe at Trews Weir * about 20 feet above sea level a well was sunk to a depth of 20 feet, probably in alluvial deposits, and bored with *7-inch bore* to a depth of *240* feet from the surface in New Red rocks. The yield is *250,000* gallons in 24 hours. The water contains a considerable quantity of carbonate of lime and chloride of sodium. Mr. Martin, C.E., Bradninch House, Exeter, furnished the following corrections of the italicised items in above account :—9-inch bore, depth 250 feet, yield 500,000 gallons

In a paper on the Exeter City Asylum Well† Mr. Andrew states that the boring was made by Shepheard and Son with a 6 inch bore in 1882, and a good supply of water obtained at 150 feet. The well section is given as follows :—

	Ft.	in.
Alluvial deposit and vegetable mould	1	0
Course sand with slight admixture of small splintered stones	6	0
Seam of ironstone (pan)	0	4
Sand	4	9
Seam of ironstone (pan)	0	4
Sand	4	0
Band of fine clay	1	6
Sand of finer grain and more compact than above	22	6
Band of ironstone	0	4
Sand	5	11
Ironstone	0	4
Sand	46	6
Very tough ironstone seam	4	0
Sand	3	0
Very hard stone much impregnated with iron oxide	16	0
Sand	29	0
Brecciated beds similar to those in the Heavitree quarries	97	6
Fine and closely compacted sand	10	0
	253	0

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* From Brit. Assoc. Rep., 1879, p. 137, and, 1882, p. 114; also paper by E. Parfitt, Trans. Dev. Assoc., vol. xii., 1880.

† Trans. Devon Assoc., vol. xx., 1888.

Mr. Andrew considered the brecciated beds as much above those in the Heavitree quarries, but there is no doubt that they must be included in that series which gives the thickness of the overlying sands about 144 feet. Mr. Andrew further states that the well at the Exminster County Asylum was sunk to a depth of 350 feet in brecciated beds, and a good supply of water obtained.

The Exminster County Asylum Well* on a site about 100 feet above Ordnance datum was sunk for 117 feet with 9 feet diameter, and bored thence to a depth of 473½ feet from the surface, the water level is at about 13 feet above sea-level, and the yield amounts to 200,000 gallons in 24 hours.

The well at the Devon County Lunatic Asylum, Exminster, is evidently another well, at 150 feet above sea level; shaft, 114 feet, with diameter of 6 feet; boring, 70 feet, with 4-inch bore. Yield, 30,000 gallons in 24 hours. Section not given. (Rep. Brit. Assoc. for 1875, p. 130.)

The composition of two samples of water in use in the Asylum is given by Dr. A. Voelcker as follows:—

	Well Water.	Water from tap in No. 5 Ward.
An imperial gallon contains in grains:—		
Organic matter and loss in heating (including oxidisable organic matter, ·176 and ·272) -	1·39	1·40
Oxides of iron and alumina and traces of phosphoric acid - - - - - - - -	·24	·25
Sulphate of lime - - - - - -	1·22	1·25
Carbonate of lime - - - - - - - -	4·66	4·87
Carbonate of magnesia - - - - - -	3·06	3·11
Chloride of sodium - - - - - - - -	3·62	3·63
Carbonates of potash and soda - - -	1·52	1·63
Soluble silica - - - - - - - - -	·90	·81
	16·61	16·95

Mr. Martin, C.E., thus explains the Exminster Asylum Wells. The first well was sunk to a depth of 116 feet, with 9 feet diameter. From that level an adit was driven to a distance of about 240 feet, and from it a boring was carried to a further depth of 355 feet 6 inches, making a total depth of 471 feet 6 inches.

Polwhele† says:—"In the neighbourhood of Exminster are several chalybeate springs." One of these in the road near an estate called Wracombe is described as an "agreeable and pretty strong chalybeate." "Near the brow of the hill above Pocombe bridge there is an agreeable strong chalybeate; so also in the vale immediately under Long-down on the right hand leading from Exeter" (west of Pocombe bridge). "A little beyond Cowley bridge runs across the road a strong and agreeable chalybeate."

Gubb's Well, in the parish of St. Thomas, near Cleave, is a pretty strong chalybeate, and contains much earth or dissolved clay, "which on standing leaves a thick deposit." Shapter refers to Cleve spring or Gubb's Well thus:—"Sp. gr., 1·002; temperature, 51°. 5′, contains free carbonic acid, sulphate of iron, muriate of iron, carbonate of iron, sulphate of lime, sulphate of alumina." He also gives:—"Perridge spring: Sp. gr., 1·003; temperature, 52°. 5′; contains free carbonic acid, muriate of iron, sulphate of iron, carbonate of iron, sulphate of lime."

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* British Assoc., 1879. Report on the Circulation of Underground Waters, etc.

† Pp. 16, 17.

"Whitestone spring: Sp. gr., 1003; temperature, 52°. 5′; in its composition very similar to the preceding, excepting that the quantity of sulphate of lime is rather less."

West Hill.

On the eastern margin of the map east of Exeter a well was sunk through the gravel patch shown on the map on the summit just north of West Hill. For 6 feet from the surface in gravel in tough clay and loam, then for 10 feet in sand-rock, in which a local seam or band of clay retained water.

Brampford Speke.

The following information respecting Brampford Speke was furnished to Mr. Pengelly by Mr. W. S. S. Gamlen:—*

"There are sixteen wells in that village, of which fourteen are from 45 to 52 feet in depth; the top water of one of these is maintained to a level only 14 feet below the surface of the ground, rising to within 6 feet in winter. The wells are in fine orange-coloured sandstone, overlaid by clean gravel; the bottoms of the wells are below the level of the Exe, but the water is derived from the high ground to the west."

A well at Brampford Speke at 140 feet above sea level was carried to a depth of 52 feet. The surface of the water was about 2 feet above the level of the River Exe. The section is as follows:—

Sandy loam, from		3 to 9 feet
Water-worn gravel from		3 to 7 feet
Lower New Red	Loose sand	10 feet
	Coarse sand	2 feet
	Sand rock	27 feet.

Very good drinking water, slightly hard and containing carbonic acid gas. Springs occur about 15 feet below the surface of the drift soil.

Hele and Silverton.

In the Culm valley, wells have been recorded at Bridge Mills (Silverton), Hele Paper Mills, and at Kensham Mills (Hele), but a section is only procurable of the first named. At Hele Paper Mills, at about 90 feet above sea level, a shaft with 10 feet diameter was sunk to a depth of 20 feet, and carried down by boring to 120½ feet from the surface. The water level stood at 60 feet above sea-level, and the yield amounts to 259,000 gallons in twenty-four hours. The variation of level in dry weather is from 15 to 20 feet.

At Kensham Mills, about 100 feet above sea level, a shaft was sunk to a depth of 40 feet, 5 feet in diameter, then the well was bored with a 7-inch bore to 200 feet from the surface. The bore hole is said to pierce the New Red Sandstone, rendering it probable that Culm Measures were reached owing to the proximity of the Culm inlier. The yield is given at 170,000 gallons in twenty-four hours, and the height of the water level at 70 feet about sea-level.

At Bridge Mills, Silverton, the well is about 80 or 90 feet above sea-level. The shaft with 5 feet diameter was sunk to a depth of 20 feet, and carried down by boring with 6-inch bore to 237½ feet from the surface. The yield in gallons per twenty-four hours was given at 315,000 in 1880, and in a synoptical table in 1882 at 180,000.* Mr. Martin, C.E., gives it at 144,000 gallons. The section of the 217 feet bored is as follows:—

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* Brit. Assoc. Rep. for 1875, p. 117, 128.

	Feet.
Sand	94
Rock	27
Marl	29
Clay and greensand	30
Gravel (water)	5
Hard clay	16
Red rock	16

This section is probably in sand-rock on sand, with hard breccia, sand, marl, and clay of the Lower New Red; it is not sufficiently specific to be of much service, and the description of the upper 20 feet sunk is lacking. The possibility that Trap may be denoted under the term rock suggests itself, as the Traps of Heazille and of Killerton Park are not far off.

Shapter mentions a spring near Thorverton "containing carbonic acid, muriate of lime, muriate of soda, sulphate of alumina, sulphate of soda (a small quantity), sulphate of iron (a trace)."

Mr. Martin's Note Book records a well at Four Mills behind the inn, close to Crediton Railway Station. The well is about 125 feet above sea-level, and was bored with a 6-inch bore to a depth of 110 feet from the surface, entirely in New Red rocks. The yield in a fortnight's test pumping for a Local Government Board Enquiry averaged 105,714 gallons in twenty-four hours.

BUILDING MATERIALS.

The area is comparatively rich in building materials. Until recently the clayey soils of the Culm Measures and of the New Red rocks were used in the building of cottages, outhouses, and walls. The clay was mixed with straw and "rammed into a boarded framework, this shifts as the work proceeds in the manner of the modern concrete building apparatus." The adobe thus formed is termed "cob."†

The New Red Marls have been extensively used for brick-making, the position of the brick pits enumerated in a preceding chapter prove that the suitability of the material is not confined to any particular horizon.

The Exeter brickyards furnish serviceable materials in the clays and brecciated clays of the Lower New Red series, which burn to a tough coarse brick.

In places the Lower New Red sands are sufficiently consolidated to be used for building purposes, as in the quarry east of Poltimore and in the quarry north of Broad Clyst Station, but this is exceptional.

Where the New Red breccias are firmly cemented, as in the Heavitree quarries, and in quarries in the neighbourhood of Exminster, they furnish good building stone.

The utility of certain of the Trap rocks for building purposes has long been known,* and may be seen in most of the old churches of the district. Perhaps the most important quarry in the district is that near Pocombe Bridge, which is referred to in the Government Report on the Building Stones of Great Britain, by the late keeper of Mining Records, R. Hunt, 1860. The quarries of Dunchideock, Budlake near Killerton, Raddon near Thorverton, and near Heazille north of Rewe, furnish good building stone. A quarry at Spencecombe presents Trap rock which can be quarried in large masses in places. The Traps are so intersected by irregular joints at the surface, and often by calcareous veins throughout, that the quality of the stone as a building material is very variable and impersistent, and requires careful selection. The blending of building stones from the breccia and from the traps is of common occurrence. The Heavitree conglomerate ("The quarries of grout stone in the parish of Heavitree") "was formerly employed in the manufacture of coarse millstones for shelling clover and separating the wheat from the close husks broken off from the ears in thrashing."†

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* Rep. Brit. Assoc. for 1879, 1880, and 1882.

† Worth, Economic Geology of Devon. Trans. Devon Assoc. for 1875, vol. 7.

The Culm Measures of the Morchard type on the north side of the Crediton Valley afford good building stone in places where the sandstones are thick bedded, hard, and not too irregularly jointed. The grits of the Exeter Culm type may here and there afford building stone, but as a rule they are more suitable for wallstone or road metal.

The Dolerites are too hard to afford good building stone, and as road metal are apt to wear unevenly, making knubbly prominences. Worth‡ says, "The best road metals of the county are derived from the trap rocks," which are tough, durable, make hard roads, and cause little dust.

Mr. Martin informs me that the sand from the sandstone quarry at Sandy Gate Turnpike is much used in Exeter building operations in making mortar. The quarry is about 70 to 80 feet deep.

MINES AND MINERALS.

De la Beche§ speaks of a great east and west fault running from near Poltimore by Huxham and Woodleigh to Venny Tedborn, and in another place|| alludes to it as "that large dislocation which runs from near Broad Clist by Newton St. Cyres to the westward." On the old geological map this is shown by a broken boundary line between the New Red and Culm rocks. Detailed investigations, however, prove this boundary to be a sinuous line which, if a great dislocation, must be shifted by many com-

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* Polwhele says the old walls of Exeter and its castle and "most of the buildings consist of scarcely any other substance than lava and tufa." The excellence of the lava as a building stone is proved "by the present appearance of the city walls." By tufa the New Red breccia is meant.

† Vancouver, Agriculture of Devon, 1808, p. 72.

‡ Trans. Devon Assoc. for 1875, pp. 209-233. Ibid. Appleton, pp. 234-246

§ Report on Geol. of Corn., Devon, etc.

|| Memoirs Geol. Sur., vol. i., p. 256.

paratively small transverse faults, and no proof of it has been obtained beyond the southerly dip of the New Red rocks between Ratsloe and Poltimore. Another east and west fault is mentioned by De la Beche as a boundary between the New Red series of Beare and the Culm inlier of Spraydown (Sprydoncote), but detailed survey did not furnish sufficient evidence of it.

A lode of Manganese is said to occur along a dislocation in the New Red rocks parallel to the first mentioned fault; and in a sketch section through Newton St. Cyres* a lead lode is shown in the Culm Measures. The occurrence of Manganese ore was indicated on the old map at (Ratsloe) Hatchleigh, Huxham, Upton Pyne, on the south of Newton St. Cyres, and near East Woodleigh (Woodley).

W. G. Maton† in 1797 mentioned that the ore was dug in a pit about 20 feet deep not far from the village of Upton Pyne, and that "the ore diminishes so much in richness in proportion to its depth, that it is worked only in a horizontal direction. We observed that the ore was in nodules of various dimensions, and generally crystallised in the inside. It is very productive—at least what is dug at the upper part of the pit, and was used in the glass-houses formerly established at Exeter, but it is now sent chiefly to London."

Dr. Berger, who visited the locality about twelve years later remarked that he "had an opportunity of making pretty accurate observations on the strata, and on the nature of the rock." The red argillaceous sandstone, at the place where the mine is excavated, forms a stratum several feet in thickness from the surface; below this is a conglomerate puddingstone, the same that is found in the parish of Heavitree, but quite disintegrated; then, a reddish compact felspar in mass, containing a few laminæ of calcareous spar, and some crystals of quartz. This last rock forms the roof of the mine.‡

R. N. Worth,§ writing in 1875, says that the Manganese mines at Upton Pyne were begun a century ago and exhausted 60 years ago. The following ores of Manganese are given by the late T. M. Hall ‖ as occurring at Upton Pyne. Manganite or grey manganese in fine prismatic crystals, Pyrolusite, earthy Manganese or "Wad," and Red Manganese or Rhodonite. Rich bunches of Manganese were found in the Culm rocks of Doddiscombsleigh and Ashton, in the vicinity of dolerite and tuff patches. Manganite in fine prismatic crystals was obtained.¶

The Manganese of Doddiscombsleigh has been obtained in the Lower Culm Measures, and occurs along the bedding as at Shute, where an adit has been driven in the chert beds. On the west side of Doddiscombsleigh Hill, in Scanniclift Copse, Manganese occurs both in decomposed vesicular igneous rock and in the hard Culm mudstones and cherty beds with which it is associated. The ore is disseminated as the result of *in situ* chemical changes in the beds and not as far as one can see in lodes.

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* De la Beche, Report, p. 295.

† Observations on the Western Counties of England, vol. i., p. 94.

‡ Trans. Geol. Soc., vol. i., p. 101.

§ Trans. Dev. Assoc., vol. vii., p. 221.

‖ Trans. Devon Assoc., vol. ii., pt. ii., p. 239.

¶ De la Beche, Report, p. 286, and Hall, op. cit.

Massive sulphate of Baryta occurs in the Culm Measures near Stone, east of Bridford. The lode strikes irregularly, varying from N. and S. to N.35°E. and S.35°W. Patches of dolerite occur in its vicinity. This is the only mine now worked in the area.

Lead ore has been raised near Newton St. Cyres. Lead mines were worked near Hennock in the adjacent map on the south (339). An abandoned mine between Leigh Cross and the north margin of the granite may indicate a lead lode on the prolongation of the fault shown on the map between Heltor and Lowton.

SOILS.

The area embraced by Sheet 325 presents a variety of soils, the granitic tract of the Dartmoor area and the heathery summits of the pebble beds of Woodbury Common being the least fertile. The Culm Measures on the south of the Crediton Valley furnish buff, grey, and yellowish, more or less, heavy clay soils suitable for wheat, but never attaining to the fertility of the New Red marls and breccias, either as regards arable or pasture lands.

Where dolerites occur the soil made by their decomposition is much more productive, and by rain wash, etc., improves the Culm soils in their immediate vicinity. On the north side of the Crediton Valley the Culm Measures often make red clay soils where purple and reddish brown grits are associated with the dark grey shales, and loamy soils are more frequent than amongst the rocks of the Exeter type. Polwhele* describes the soils of the parishes of Whitestone, Holcombe Burnell, Dunsford, and Doddiscombsleigh, as "a tough clay, with a dense black whin or iron-stone"; the latter evidently denotes the dolerite patches. He speaks of strata of "red marly loam, that is not to be exceeded in richness and fertility by any in the county, or perhaps in any part of England," as beginning at Plymstock, and continuing to Ashprington, Paignton, Cockington, Teignmouth, Powderham, Broad Clyst, and Bradninch. "This soil is of great depth, and consists of a firm rocky marl, easily friable when exposed to the air or in water, soapy to touch, effervesces with acids, producing very rich grass, on which cattle fatten speedily. Very strong crops of corn are produced on this soil, but it is considered more profitable to keep in grass for bullocks. It answers very well as a manure for poorer lands; but it contains so much calcareous earth, that it must be laid on sparingly."

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* History of Devonshire, pp. 42 and 45.

In this description we seem to have a blending of the Devonian volcanic series of Ashprington with Lower Devonian rocks, the Trap patches of the Exeter area and New Red breccias and marls. The New Red rocks of Exminster, Exeter, Broad Clyst, Bradninch, Silverton, and the Crediton valley make rich soils. Polwhele describes the red soil on the Exminster hills as a particularly fine loam. Some of the inhabitants informed him that the wheat produced there was thinner hulled and had a larger proportion of white flour per bushel than any other. As the British farmer is not given to exaggerate the productiveness of his land we may accept this statement with a very small pinch of salt.

Vancouver, in an exhaustive Report on the Agriculture of Devonshire, gives the produce of the different crops in various parts of the district with the agricultural methods then used (1808). As a supplement to, and, in some respects only, an advance on Polwhele's geological descriptions, the work is well worthy of perusal, and in a soil map the position of the Devonian and Culm Measure limestones and calcareous slates (indiscriminately) is indicated almost as precisely as in the earliest Geological Survey maps. The following passages are quoted from Vancouver:—(Page 44.) "Red rubbly gravel and grout stone which continues through Exminster, Shillingford, Alphington, and Ide, to Exeter." "Proceeding thence through Newton St. Cyres, Crediton," etc.—"the rich red loam is found to vary in its strength and quality, from its lying at a greater or less distance on a deep bed of red rubbly gravel, or from its vicinity to a red pumice-like marl, which in the parishes of Colebrooke and North Tawton, is found between the soil and a hard brown rock. . . . This latter is justly esteemed by far the strongest and richest land. Under the former description of soil and substrata may fairly be classed all that beautiful country lying along (p. 45) the Creedy, the Exe, and the Culm rivers. . . . Along these water-courses are large and valuable tracts of marsh and meadow grounds, subject to annual inundation." In p. 24, "Cadbury, with the northern parts of Stokely Pomeroy, Upton-hellions, Sandford . . . are generally covered with a tender loam of a dark grey cast on a shilloty understratum; a reddish brown free loam on a rough rubbly subsoil, or a loose sandy loam of a bright red colour on a stratum of argillaceous smooth pebbly gravel: the whole, with a large proportion of good meadow and pasture land, is well calculated for the culture of wheat, barley, oats, pease, turnips, tares, and clover." "The north-western parts of Silverton and Bradninch . . . may with great propriety be added to this description."

In this last quotation we have the soil of the Lower New Red gravels and the Culm rocks on the north border of the Crediton valley described; in the following the Culm soils on the south of the Crediton valley. (P. 26.) "The country for the first two miles after passing Crediton to the southward, and towards St. Mary Tedborne consists of the same red loam." . . . "Approaching the foot of Old Ridge hills, this suddenly disappears in a moist grey loam on a stratum of brown and yellow clay, and that lying tc a considerable depth on the shaley rock. This grey loam, but of a drier nature, and on the schistus or slaty rock "† (P. 27) "continues for about half a mile eastward from the church at Whitestone, where it again unites with the red land district. Descending to the valley southwardly from the church at Whitestone, and crossing near West Kent farm, this grey loam continues, till it reaches the same character of soil, although generally of an inferior quality, in the parish of Holcombe-burnell.

"The country lying west of Whitestone church, including the parishes of St. Mary Tedborne, Christow, etc. . . . consists of a dark grey, or rather brownish coloured loam, intercepted at various depths from the shaley rock by a subsoil of moist brown, blue, and yellow clay." (P. 29) "the western parts of Doddiscombeleigh and Dunchideock (their eastern quarters lying partly within the red land district) consists of a brown tender mould of a good staple on a Dunstone rubble." Wheat tillage in the neighbourhood of Whitestone is given on p. 154; in the Exeter red rock district on p. 165.

Risdon* alludes to the "plenty of good cyder fruit" in the orchards in the neighbourhood of Alphington. In pp. 15-16 he discusses the relative merits of the "blue marle" and "red marle"—doubtless referring to the soils of the palæozoic rocks and those of the igneous and New Red districts.

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* Risdon's Survey of Devon, Exeter, 1785, p. 25.

APPENDIX.

LIST OF PRINCIPAL WORKS ON THE GEOLOGY OF THE DISTRICT.

1793–1806. **POLWHELE, REV. R.** The History of Devonshire. Three vols. fol. London.

1808. **VANCOUVER, C.** General View of the Agriculture of the County of Devon. 8vo. London.

1811. **BERGER, DR. J. F.** Observations on the Physical Structure of Devonshire and Cornwall. *Trans. Geol. Soc.*, ser. 1, vol. i., p. 93.

1821. **CONYBEARE, REV. J. J.** On the Red Rock Marle, or Newer Red Sandstone. *Ann. of Phil.*, ser. 2, vol. i. p. 254.

1822. **CONYBEARE, REV. W. D.**; and **W. PHILLIPS.** Outlines of the Geology of England and Wales. Part. i. 8vo., London.

1823. **CONYBEARE, REV. J. J.** On the Geology of Devon and Cornwall. *Ann. of Phil.* ser. 2, vol. v., p. 184, and vol. vi., p. 35.

1835. **DE LA BECHE (SIR), H. T.** Note on the Trappean Rocks associated with the (New) Red Sandstone of Devonshire. *Proc. Geol. Soc.*, vol. ii., p. 196.

1838. **SHAPTER, DR. T.** A Sketch of the Geology of Exeter and its neighbourhood. 8vo. Exeter

1839. **DE LA BECHE (SIR), H. T.** Report on the Geology of Cornwall, Devon, and West Somerset (Geological Survey). 8vo. London.

1840. **OTTLEY.** On some Specimens from the New Red Sandstone (near Exeter). *Proc. Geol. Soc.*, vol. iii., p. 298.

1842. **DE LA BECHE, SIR H. T.** On the connection between Geology and Agriculture in Cornwall, Devon, and West Somerset. *Journ. Roy. Agric. Soc.*, ser. 1, vol. iii., p. 21.

1842. **GODWIN-AUSTEN, R. A. C.** On the Geology of the South-east of Devonshire. *Trans. Geol. Soc.*, ser. 2, vol. vi., p. 433. (This includes the substance of papers printed in abstract in 1834, *Proc. Geol Soc.*, vol. ii., p. 102; in 1836, *Ibid.* p. 414; in 1839, *Ibid.* vol. iii., p. 123; and in 1840, *Ibid.* p. 286.)

1842. **SHAPTER, DR. T.** The Climate of South Devon, etc. (Geological Map). 8vo. London. (2nd Edition, 1862.)

1845. **WILLIAMS, REV. D.** On the Exeter Amygdaloid. *Rep. Brit. Assoc.* for 1844, *Trans. of Sections*, p. 55.

1851. **GODWIN-AUSTEN, R. A. C.** On the Superficial Accumulations of the Coasts of the English Channel, and the changes they indicate. *Quart. Journ. Geol. Soc.*, vol. vii., p. 118.

1854. Murchison, Sir R. I. Siluria. The History of the Oldest known Rocks containing Organic Remains.
8vo. London (pp. 256-266). Later editions in 1859 and 1867

1861. Oliver, Rev. G. The History of the City of Exeter. 8vo. Exeter.

1862. Pengelly, W. The Red Sandstones and Conglomerates of Devonshire. Part i. *Trans. Plymouth Inst.* for 1861-2, p. 15

1863. Pengelly, W. The Red Sandstones, Conglomerates, and Marls of Devonshire. Part ii. *Trans. Plymouth Inst.* for 1862–3, p. 15.

1865. Pengelly, W. The Red Sandstones, Conglomerates, and Marls of Devonshire. Part iii. *Trans. Plymouth Inst.* for 1864–65, p. 15.

1865. Vicary, W. On the Feldspathic Traps of Devonshire.
Trans. Devon Assoc., vol. i., part iv., p. 43.

1867. Vicary, W. On the Source of the Murchisonite Pebbles and Boulders in the Triassic Conglomerates of Devonshire.
Trans. Devon Assoc., vol. ii., p. 200

1868. Hall, T. M. On the Mineral Localities of Devonshire.
Trans. Devon Assoc., vol. ii., p. 332.

1869. Hall, T. M. On the Mineral Localities of Devonshire.
Trans. Devon Assoc., vol. iii., p. 75.

1869. Whitaker, W. On the Succession of Beds in the "New Red" on the South Coast of Devon, and on the Locality of a New Specimen of Hyperodapedon.
Quart. Journ. Geol. Soc., vol. xxv., p. 152.

1875. Ormerod, G. W. On the Murchisonite Beds of the Estuary of the Exe, and an attempt to classify the Beds of the Trias thereby.
Quart. Journ. Geol. Soc., vol. xxxi.. pp. 346–54.

1875. Worth, R. N. The Economic Geology of Devon.
Trans. Devon Assoc., vol. vii., pp. 209–233.

1875. Ussher, W. A. E. On the Sub-divisions of the Triassic Rocks between the Coast of West Somerset and the South Coast of Devon. *Geol. Mag.*, dec. 2, vol. ii., pp. 163-168.

1876. Ussher, W. A. E. On the Triassic Rocks of Somerset and Devon.
Quart. Journ. Geol. Soc., vol. xxxii., pp. 367–394.

1880. Parfitt, E. On the Boring for Water and the Sinking of two Wells, at the two large Breweries, the "City" and "St. Anne's," in Exeter. *Trans. Devon Assoc.*, vol. xii., pp. 447–454.

1888. Andrew, T. Some notes on the well at the Exeter City Asylum.
Trans. Devon Association, vol. xx., pp. 123–128.

1888. Andrew, T. Some notes on a natural pipe from a sand pit in the Breccia Series in the Parish of Heavitree.
Trans. Devon Association, vol. xx., pp. 378-382.

1888. Irving, Rev. A. The Red-Rock Series of the Devon Coast section.
Quart. Journ. Geol. Soc., vol. xliv., pp. 149–163. Supplementary Note, *Ibid.*, vol. xlviii., pp. 68-77. (1892.)

1890. WORTH, R.N. The Igneous Constituents of the Triassic Breccias and Conglomerates of South Devon.
Quart. Journ. Geol. Soc., vol. xlvi., pp. 69–81.

1892. HOBSON, B. On the Basalts and Andesites of Devonshire, knows as "Felspathic Traps."
Quart. Journ. Geol. Soc., vol. xlviii., pp. 496-507.

1892. HULL, PROF. E. A Comparison of the Red Rocks of the South Devon Coast with those of the Midland and Western Counties.
Quart, Journ. Geol. Soc., vol. xlviii., pp. 60–67.

1892. USSHER, W. A. E The British Culm Measures.
Proc. Somersetshire Arch. and Nat. Hist. Soc., vol. xxxviii., pp. 111–219.

1892. USSHER, W. A. E. Permian in Devonshire.
Geol. Mag., dec. 3., vol. ix., pp. 247–250.

1897. GEIKIE, SIR A. The Ancient Volcanoes of Great Britain, vol. ii. pp. 32–36, and 94–100.

1899. USSHER, W. A. E. Excursion to Exeter, etc.
Proc. Geol. Assoc., vol. xvi., pp. 148–152.

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